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Goods Movement Emission Reduction Action Plan

March 2008

Funding: The preparation of this report was financed in part through grants from the United States Department of Transportation.

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Prepared for

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Executive Summary

Southern California is perhaps the nation's most important gateway for international trade. By all accounts, goods movement in the region is expected to grow significantly in the future, straining the system of highways, ports, railroads, intermodal yards, and airports that is, in some locations, already overburdened. Container throughput at the Ports has doubled in just the last eight years, and forecasts suggest it will double again between 2006 and 2020. SCAG modeling suggests that regional daily truck VMT will grow from 28.1 million in 2003 to 51.3 by 2035, an 83% increase. And train volumes are forecast to more than double between 2000 and 2025.

While goods movement brings economic benefits to the region, it also has serious adverse impacts on air quality, noise, congestion, and public health. In 2005, goods movement was responsible for approximately 432 tons per day of NOx emissions and 17 tons per day of PM2.5 emissions in the South Coast Air Basin, or 42% and 16% of all regional NOx and PM2.5 emissions, respectively. Looking forward under a baseline scenario that reflects only currently adopted regulations, total goods movement NOx and PM2.5 emissions will decline by 45% and 21%, respectively, between 2005 and 2020, primarily due to the effects of recent emission standards for heavy-duty trucks, and to a lesser extent, emission standards for locomotives, harbor craft, and off-road cargo handling equipment. Even with these improvements, however, the region faces considerable challenges in meeting federally-mandated air quality goals and minimizing localized impacts of diesel particulate emissions.

A number of major efforts are underway to reduce goods movement emissions in Southern California, including plans developed by the Ports of Los Angeles and Long Beach, the South Coast Air Quality Management District, and the California Air Resources Board. This study is intended to complement these efforts by helping SCAG and other agencies achieve the region's air quality goals as they make decisions about investments in transportation infrastructure and mobile source controls. The document focuses primarily on truck and railroad locomotive emission reduction strategies, since SCAG is actively engaged in planning improvements to highway and railroad systems. This Action Plan complements a much lengthier technical report that presents a detailed emission reduction and cost effectiveness analysis for more than 40 individual strategies (see *Analysis of Goods Movement Emission Reduction Strategies: Task 1 Final Report*, January 2008, available at http://www.scag.ca.gov/goodsmove/pdf/AnalysisGoodsMovementEmission_FinalReport.pdf).

On-Road Trucks

On-road trucks perform the bulk of goods movement in the SCAG region. They include tractor-trailer combination trucks as well as single-unit trucks used in applications like urban pick-up and delivery, waste hauling, and construction. Trucks are responsible for approximately 300 tons of NOx emissions and 10 tons of PM2.5 emissions per day. A variety of strategies can reduce emissions from trucks, including replacement with cleaner trucks, repowering (replacing the engine), emission control retrofits, alternative fuels, as well as operational improvements and infrastructure projects to reduce congestion and idling. All of these options are available today. In particular, trucks meeting the U.S. EPA's stringent 2007/2010 emissions standards are excellent candidates to replace older, high-polluting trucks. In addition, a variety of emission control retrofit devices are commercially available and certified by the Air Resources Board for their effectiveness.

Several initiatives are underway that will likely have a major influence on the options for reducing truck emissions over the next decade. The California Air Resources Board (CARB) is in the process of adopting in-use truck rules that would apply to existing vehicles already on the road. As currently envisioned, the rules would be phased in to require that all truck engines meet the 2007 U.S. EPA emissions standard by 2013, and all truck engines meet the 2010 U.S. EPA emissions standard by 2021. Another CARB rule would target trucks serving ports and intermodal facilities, with more immediate clean-up deadlines. If adopted, these rules would modernize almost all remaining California-registered trucks in the SCAG region on a mandatory basis by 2020. While these rules may be modified before they are adopted, and they may also face legal challenges, it is likely that in-use truck rules will take effect in some form in the next five to ten years. In this event, the CARB rules would pre-empt many of the most effective truck emission reduction strategies that otherwise could have been implemented for 2020 as part of a voluntary incentive program.

The other major development is the San Pedro Bay Ports Clean Truck Program, part of the Ports' *Clean Air Action Plan*. Both Ports have approved a progressive ban on older trucks as well as a container fee to fund replacement or retrofitting of the existing fleet. Ultimately, the Ports hope to retrofit or replace nearly all of the 16,000-odd trucks that serve the Ports.

Rail Locomotives

Heavy volumes of trains traverse the SCAG region and carry much of the goods to and from the ports. Freight rail locomotives are used in two primary ways: as line-haul engines or as switching engines. Railroad locomotives contribute approximately 30 tons of NOx emissions and 0.8 tons of PM2.5 emissions per day. Potential strategies to reduce locomotive emissions include replacement or repowering with cleaner engines, emission control retrofit devices, use of clean switchers such as hybrids and GenSet locomotives, idle reduction devices, railroad electrification, as well as capacity improvements to smooth train flows and reduce idling.

The U.S. EPA announced new emission standards for locomotives in March 2008. The new standards include retrofit of existing equipment as well as new engine emission standards (Tier 3 and Tier 4). The Tier 4 standards are analogous to the 2007/2010 heavy-duty truck standards and will result in large reductions in NOx and PM emission rates when they take effect in 2015.

In contrast to trucks, the most effective emission reduction strategies for locomotives are not likely to be available for the next five to seven years. The technologies that will be needed for locomotives to meet the new emission standards are still under development. Locomotive retrofit devices are not currently available and are unlikely to be available as commercial products by 2010. By 2015, however, Tier 4 engines and retrofit kits are expected to be available.

Priorities for 2010 and 2020

The challenge for public agencies is to maximize the benefit of government resources dedicated to goods movement environmental mitigation. Strategies that can achieve this objective are those that:

1. Can achieve large emission reductions
2. Are relatively cost effective
3. Do not face major implementation barriers
4. Are unlikely to occur absent additional government support

Given the continuing evolution of emission control requirements, the most effective use of public resources for emission reductions in the near term is strategies that focus on trucks, while longer term investments should focus on railroads.

In order to illustrate potential strategy priorities for 2010 and the level of emission reduction that could be achieved for a given level of public investment, this document presents three hypothetical programs of on-road heavy-duty truck strategies. In all three programs, the objective is to obtain the largest emission reduction benefit. To construct these programs, funds were allocated to the most cost-effective truck strategies up to a target participation level until the maximum funding level was reached. Table ES-1 shows the details of the three programs, reflecting total investment levels of $30 million, $100 million, and $300 million.

Table ES-1: Three Hypothetical Emission Reduction Programs for 2010

HHDT Strategy	Target Model Year	Potential Truck Population	Assumed Market Penetration	Emission Reduction Benefits (tons/year) NOx	PM2.5	ROG	Total Cost (million)
Repower with 2003-2006 Engine with DPF	1999-2002	8,089	6.65%	408	23	67	$21.5
Retrofit with DPF	1999-2002	8,089	6.45%	--	22	61	$4.4
	2003-2006	6,281	6.45%	--	25	23	$4.1
Total		14,369	10.2%	408	70	151	$30.0
Replace with 2007+ truck	1999-2002	8,089	10.0%	1,663	61	154	$62.4
Repower with 2003-2006 Engine with DPF	1999-2002	8,089	10.0%	613	34	101	$32.3
Retrofit with DPF	1999-2002	8,089	4.0%	--	14	38	$2.8
	2003-2006	6,281	4.0%	--	16	14	$2.5
Total		14,369	15.3%	2,276	70	151	$100.0
Replace with 2007+ truck	1994-1998	9,708	20.0%	4,186	172	445	$149.8
	1999-2002	8,089	20.0%	3,326	123	309	$124.8
Repower with 2003-2006 Engine with DPF	1999-2002	8,089	7.9%	481	27	79	$25.4
Total		17,797	23.6%	7,993	322	833	$300.0

Similarly, Table ES-2 shows three hypothetical programs of the most cost-effective strategies to reduce locomotive emissions in 2020. The first program (for $30 million) assumes that locomotive retrofit devices become commercially available and cost effective by 2020. The second and third programs rely on replacement of older locomotives with new hybrid switchers or engines meeting Tier 4 standards.

For context, the emission reductions resulting from the programs presented above can be compared against the emission reductions needed to achieve attainment of the ambient PM2.5 and 8-hour ozone standards, as presented in the region's 2007 Air Quality Management Plan. Program 3 in 2010 would contribute 11% of the NOx reductions and 6% of the PM reductions needed for PM2.5 attainment. Contributions toward the targets for ozone attainment are more modest. Program 3 in 2020 would contribute 1.4% of the NOx reductions needed for ozone attainment.

Table ES-2: Three Hypothetical Emission Reduction Programs for 2020

Locomotive Strategy	Locomotive Type	Number of Locomotives	Emission Reduction Benefits (tons/year) NOx	PM2.5	ROG	Total Cost (million)
Retrofit with DPF	Line haul	35	0	11.8	13.5	$5.3
	Switcher	40	0	1.5	2.2	$3.0
Retrofit with SCR	Line haul	35	787	0	0	$14.0
	Switcher	40	88	0	0	$8.0
Total		150	875	13.3	15.7	$30.3
Replace with Hybrid Switcher	Line haul	N/A				
	Switcher	20	48	0.8	0.9	$15.0
Replace Rebuilt Tier 2 with Tier 4	Line haul	20	399	5.6	6.7	$48.0
	Switcher	25	53	0.8	1.2	$37.5
Total		65	500	7.3	8.8	$100.5
Replace with Hybrid Switcher	Line haul	N/A				
	Switcher	36	86	1.5	1.6	$27.0
Replace Rebuilt Tier 2 with Tier 4	Line haul	91	1,818	25.4	30.5	$218.4
	Switcher	36	76	1.2	1.7	$54.0
Total		163	1,979	28.2	33.8	$299.4

1. Introduction

Southern California is perhaps the nation's most important gateway for international trade. The Ports of Los Angeles and Long Beach (the Ports) together handle 11% of the nation's trade in value terms, far more than any other trade gateway. Nearly 36% of all U.S. waterborne container traffic passes through the two ports.[1] The SCAG region also supports a tremendous amount of domestic manufacturing, warehousing/transloading, and retailing activity, all of which relies on the movement of goods. Major highways like I-5, I-710, I-605, and SR-60 frequently carry more than 25,000 trucks per day, while more than 150 freight trains per day traverse the region on east-west rail lines.

By all accounts, goods movement in the region is expected to grow significantly in the future, straining the system of highways, ports, railroads, intermodal yards, and airports that is, in some locations, already overburdened. Container throughput at the Ports has doubled in just the last eight years, and forecasts suggest it will double again between 2006 and 2020.[2] SCAG modeling suggests that regional daily truck VMT will grow from 28.1 million in 2003 to 51.3 by 2035, an 83% increase.[3] And train volumes are forecast to more than double between 2000 and 2025.[4]

SCAG estimates that one out of every seven jobs in Southern California depends on trade. Any significant deterioration in the performance of the freight system could have serious economic and environmental repercussions for the region. SCAG, together with state and local agencies, is working to ensure the region continues to benefit from a high level of environmentally sensitive freight mobility. SCAG's draft 2008 Regional Transportation Plan identifies a number of needed goods movement infrastructure investments including dedicated lanes for clean technology trucks, railroad capacity improvements, and grade crossing separation projects. SCAG is also evaluating other longer-term improvements to enhance goods movement, such as a high speed rail transport system for freight and an inland port.

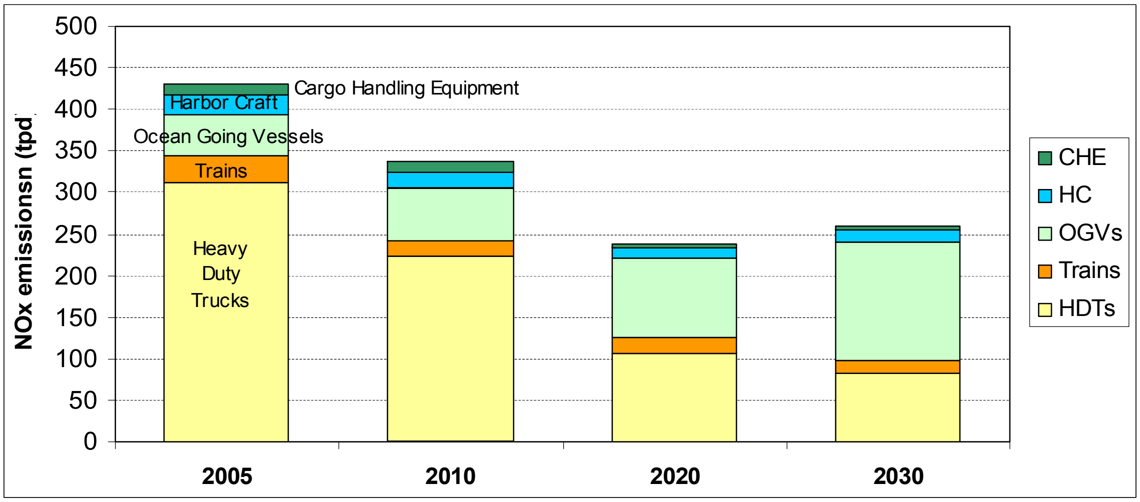
1.1. Summary of Goods Movement Emissions

While goods movement brings economic benefits to the region, it also has serious adverse impacts on air quality, noise, congestion, and public health. In 2005, goods movement was responsible for approximately 432 tons per day (tpd) of NOx emissions and 17 tpd of PM2.5 emissions in the South Coast Air Basin (SoCAB), or 42% and 16% of all regional NOx and PM2.5 emissions, respectively. Looking forward under a baseline scenario that reflects only currently adopted regulations, total goods movement NOx and PM2.5 emissions will decline by 45% and 21%, respectively, between 2005 and 2020, primarily due to the effects of recent emission standards for heavy-duty trucks, and to a lesser extent, emission standards for locomotives, harbor craft, and off-road cargo handling equipment. Even with these improvements, however, the region faces considerable challenges in meeting federally-mandated air quality goals and minimizing localized impacts of diesel particulate emissions. Figures 1-1 and 1-2 illustrate the expected trend in Southern California goods movement emissions, absent new regulations or emission reduction programs.

As stated previously, goods movement emissions have significant public health effects. NOx is a precursor to ground-level ozone, which can trigger a variety of health problems including aggravated asthma, reduced lung capacity, and increased susceptibility to respiratory illnesses like pneumonia and bronchitis. Many scientific studies have linked breathing PM to a series of significant health problems, including aggravated asthma, difficulty breathing, chronic bronchitis, heart attacks, and premature death. Diesel exhaust is of specific concern, because it is likely to be carcinogenic to humans by inhalation and to pose a hazard from non-cancer effects such as increased respiratory symptoms and inflammation, and increased respiratory and cardiovascular hospitalizations. The South Coast Air Quality Management

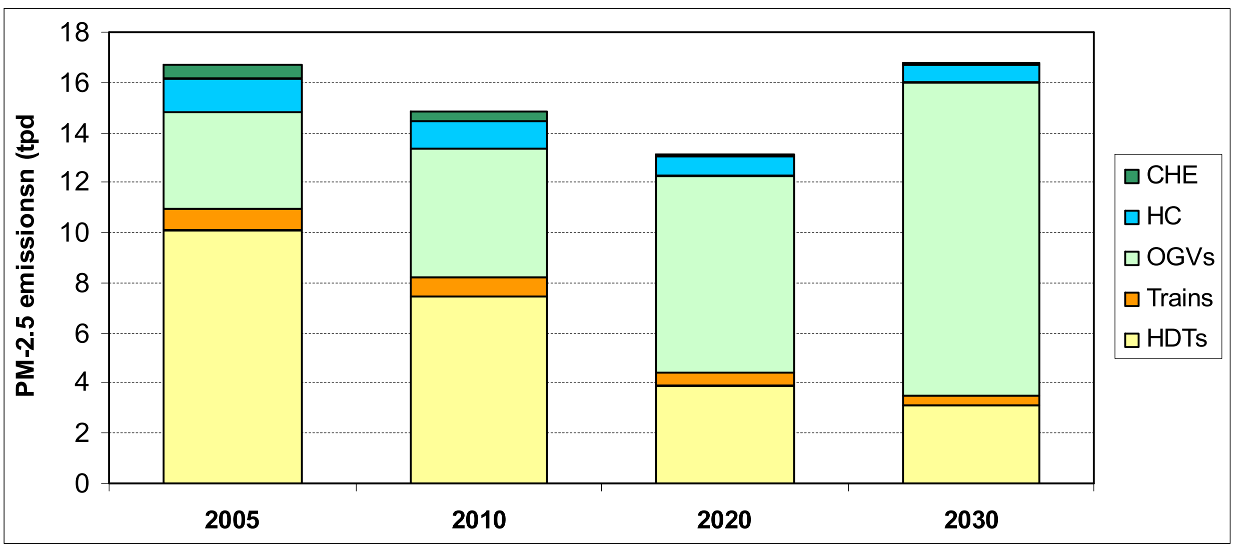
District's MATES-III study found that 70% of the cancer risk in the region was caused by diesel particular matter, most of which comes from goods movement sources.[5]

Figure 1-1: Baseline Goods Movement NOx Emissions (South Coast Air Basin)



Source: Developed based on *2007 Air Quality Management Plan*, South Coast Air Quality Management District, and information provided by the California Air Resources Board and U.S. EPA.

Figure 1-2: Baseline Goods Movement PM2.5 Emissions (South Coast Air Basin)



Source: Developed based on *2007 Air Quality Management Plan*, South Coast Air Quality Management District, and information provided by the California Air Resources Board and U.S. EPA.

The South Coast Air Basin is classified as a Severe-17 nonattainment area under the national 8-hour ozone standard and a nonattainment area under the national PM2.5 standards. The required attainment dates (end of year) under these standards are 2023 for ozone, 2014 for annual PM2.5, and 2019 for 24-hour PM2.5.

1.2. Related Efforts

A number of major efforts are underway to reduce goods movement emissions in Southern California, including plans developed by the Ports of Los Angeles and Long Beach, the South Coast Air Quality Management District (SCAQMD), and the California Air Resources Board (CARB). These three agencies share geographic jurisdiction in the region but have distinct air quality responsibilities. The Ports can regulate certain emissions sources, such as drayage trucks and cargo-handling equipment that operate on Port property, through their roles as landlords and providers of access to shipping facilities. SCAQMD has regulatory and permitting authority within the South Coast Air Basin, and cooperates with CARB in designing the region's strategy for air quality attainment and health risk reduction. SCAQMD is responsible for the overall development and implementation of the District's Air Quality Management Plan (AQMP), which forms the South Coast Air Basin component of the State Implementation Plan as required under the Federal Clean Air Act. CARB has sole authority to set statewide fuel specifications and emission standards for engines and vehicles, and to regulate associated control technologies.

San Pedro Bay Ports Clean Air Action Plan

In November 2006, the Ports of Los Angeles and Long Beach released the first *San Pedro Bay Ports Clean Air Action Plan* (CAAP).[6] Reflecting an unprecedented degree of high-level cooperation between the Ports on air quality issues, the plan describes measures that the two ports will take to reduce emissions related to port operations. SCAQMD, CARB, and the U.S. Environmental Protection Agency (U.S. EPA) assisted in developing the plan.

The CAAP is a five-year plan that identifies goals, emission reductions, and budgetary needs through 2011. It includes 12 source-specific control measures, summarized in Table 1-1.

Table 1-1: Control Measures in Clean Air Action Plan

Emissions Source	Measure No.	Name
Trucks	SPBP-HDV1	Performance Standards for On-Road Heavy-Duty Vehicles
	SPBP-HDV2	Alternative Fuel Infrastructure for Heavy-Duty Natural Gas Vehicles
Ocean-Going Vessels	SPBP-OGV1	OGV Vessel Speed Reduction (VSR)
	SPBP-OGV2	Reduction of At-Berth OGV Emissions
	SPBP-OGV3	OGV Auxiliary Engine Fuel Standards
	SPBP-OGV4	OGV Main Engine Fuel Standards
	SPBP-OGV5	OGV Main & Auxiliary Engine Emissions Improvements
Cargo-Handling Equipment	SPBP-CHE1	Performance Standards for CHE
Harbor Craft	SPBP-HC1	Performance Standards for Harbor Craft
Railroads	SPBP-RL1	PHL Rail Switch Engine Modernization
	SPBP-RL2	Existing Class 1 Railroad Operations
	SPBP-RL3	New and Redeveloped Rail Yards

Source: *San Pedro Bay Ports Clean Air Action Plan*, November 2006.

More recently, the Ports have announced a Clean Truck Program to implement the goals for reducing truck emissions contained in the CAAP. The program includes a ban on older trucks at the Ports, to be phased in starting this year (see Section 2.2 for more information). The Ports have approved a container fee of $35 per TEU in order to fund the replacement and retrofit of trucks serving the Ports.

If implemented as planned, the entire CAAP would reduce port-related truck, OGV, and CHE emissions of NOx and diesel particulate matter by 46% and 52%, respectively, as compared to baseline emissions in 2011 that incorporate all existing regulations. (Reductions from railroads and harbor craft are not fully quantified in the plan.)

SCAQMD 2007 Air Quality Management Plan

On June 1, 2007, the Governing Board of the South Coast Air Quality Management District adopted the *2007 Air Quality Management Plan* (AQMP).[7] The AQMP is prepared every three years and is submitted to CARB for inclusion in the State Implementation Plan (SIP). The AQMP estimates current and projected baseline emissions as well as the emission reduction targets necessary to achieve attainment of the PM2.5 and 8-hour ozone standards, shown in Table 1-2.

Table 1-2: Emission Reduction Targets for Attainment, South Coast Air Basin (tons per day)

Standard and Date	NOx	VOC	PM2.5	SOx
PM2.5 Standard, by 2014	192	59	14	24
Ozone Standard, by 2023	383	116	N/A	N/A

Source: *Final 2007 Air Quality Management Plan.*

CARB Emission Reduction Plan for Ports and Goods Movement in California

In April 2006, the California Air Resources Board approved the *Emission Reduction Plan for Ports and Goods Movement in California*.[8] The plan establishes statewide and Southern California goals related to goods movement emissions, including:

- South Coast 2015 Goal: To reduce projected 2015 emissions of NOx from ports and international goods movement in the South Coast by 30%.
- South Coast 2020 Goal: To reduce projected 2020 emissions of NOx from ports and international goods movement in the South Coast by 50%.

To achieve these goals, CARB is pursuing a variety of regulatory measures to reduce emissions from trucks, locomotives, ocean-going vessels, and harbor craft. Most notably, CARB has proposed rules that would require all in-use heavy duty trucks to meet the 2007 U.S. EPA standards by calendar year 2013, and to meet the 2010 standards by 2021. These rules are described further in Section 2.2.

1.3. Purpose and Organization

SCAG recognizes that a number of agencies and organizations have an interest in implementing goods movement emission reduction strategies. This study is intended to complement the efforts described in the previous section, as well as other related efforts. SCAG has responsibility for ensuring that the long-term transportation planning requirements for emission reductions from on-road mobile sources are met by SCAG's Regional Transportation Plan (RTP). SCAG also has responsibility to ensure that the short-term implementation requirements of the Transportation Conformity Rule are met by SCAG's biennial Regional Transportation Improvement Program (RTIP).

The purpose of this study is to help SCAG and other agencies achieve the region's air quality goals as they make decisions about investments in transportation infrastructure. This Action Plan complements a much lengthier technical report that presents a detailed emission reduction and cost effectiveness analysis for more than 40 individual strategies (see *Analysis of Goods Movement Emission Reduction Strategies: Task 1 Final Report*, January 2008, available at http://www.scag.ca.gov/goodsmove/pdf/AnalysisGoodsMovementEmission_FinalReport.pdf).

The remainder of this document presents recommendations for mitigating the emissions from the goods movement for which SCAG is planning. This Action Plan focuses primarily on truck (Section 2) and railroad locomotive (Section 3) emission reduction strategies, since SCAG is actively engaged in planning improvements to highway and railroad systems. The Action Plan places less emphasis (Section 4) on other goods movement emissions sources (i.e., ocean going vessels, harbor craft, off-road cargo handling equipment) because these sources are being addressed by the Ports and CARB and because SCAG does not (directly) plan for improvements to these systems. This document does not address emissions from goods movement at airports.

2. On-Road Truck Strategies

2.1. Introduction

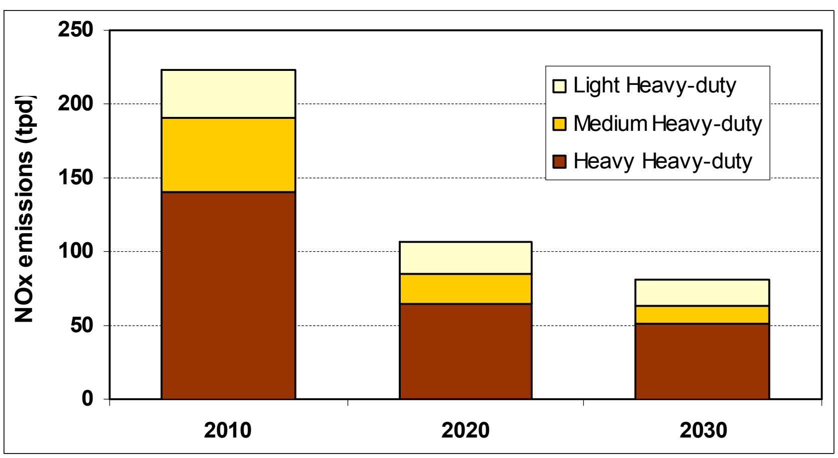
On-road trucks perform the bulk of goods movement in the SCAG region. They include tractor-trailer combination trucks as well as single-unit trucks used in applications like urban pick-up and delivery, waste hauling, and construction. CARB defines "heavy-duty trucks" to be those with a gross vehicle weight rating (GVWR) of more than 8,500 pounds. This 8,500 pound threshold is roughly the boundary between 4-tire trucks used for personal travel (e.g., pick-ups and SUVs) and 4-tire or 6-tire trucks used for commercial purposes.

CARB uses three classes of heavy-duty trucks, as follows:

- Light heavy-duty trucks: 8,501 - 14,000 lb GVWR
- Medium heavy-duty trucks: 14,001 - 33,000 lb GVWR
- Heavy heavy-duty trucks: 33,001+ lb GVWR

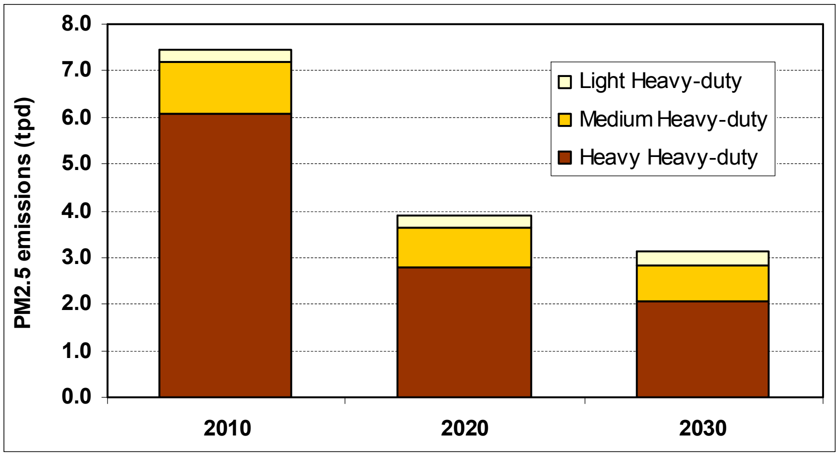
Figures 2-1 and 2-2 show projected baseline emissions from heavy-duty trucks in the South Coast Air Basin. Total truck emissions are expected to decline by approximately 60% between 2010 and 2020, and 25% from 2020 to 2030, due to U.S. EPA emission standards for new on-road heavy-duty vehicles, as described below. The effects of the EPA emission standards will more than offset the projected growth in truck VMT from 2010 to 2030.

Figure 2-1: Baseline Heavy-Duty Truck NOx Emissions in the South Coast Air Basin



Source: *2007 Air Quality Management Plan*, South Coast Air Quality Management District
Note: Baseline does not reflect proposed CARB standards for in-use trucks or the Ports proposed Clean Truck Program

Figure 2-2: Baseline Heavy-Duty Truck PM2.5 Emissions in the South Coast Air Basin



Source: *2007 Air Quality Management Plan*, South Coast Air Quality Management District
Note: Baseline does not reflect proposed CARB standards for in-use trucks or the Ports proposed Clean Truck Program

2.2. Current Rules and Programs That Affect Truck Emissions

The options for SCAG to promote a reduction in truck emissions depend heavily on government regulations affecting emissions as well as other voluntary programs targeting this sector. Therefore, it is important to briefly review these rules and programs.

The U.S. EPA adopted strict **emission standards for new on-road heavy-duty vehicles** that take effect in 2007 and 2010. Under these new standards, both NOx and PM emissions must be ten times lower than under the previous standard, and the 2010 standards represent a 25-fold reduction compared to emission standards in the early 1990s. Thus, emissions from 2010 model year and later trucks will be dramatically lower than from most trucks in use today. As a result of these new standards, on-road truck emissions will decline significantly over the next decade, as illustrated in Figures 2-1 and 2-2 above, despite growth in VMT.

Table 2-1: EPA Emission Standards for Heavy-Duty Trucks (g/bhp-hr)

Model Year	NOx	PM
1988-89	10.7	0.6
1990	6.0	0.6
1991-93	5.0	0.25
1994-97	5.0	0.1
1998-2003	4.0	0.1
2004-2006 [a,b]	2.0	0.1
2007	2.0	0.01
2010 [c]	0.2	0.01

Note a: Under a consent decree with U.S. EPA, engine makers implemented the 2004 standards in October 2002.

Note b: Standards allow the option of 2.4 g/bhp-hr NMHC+NOx, or 2.5 g/bhp-hr NMHC+NOx and 0.5 NMHC.

Note c: NOx standards are phased-in 2007-2010; most 2007-2009 engines meet a 1.1 g/bhp-hr NOx standard.

The U.S. EPA emission standards apply only to new vehicles in the year of their manufacture. CARB is in the process of adopting **in-use truck rules** that would apply to existing vehicles already on the road. At present, CARB has adopted rules to reduce emissions from two relatively small segments of in-use trucks: refuse trucks and public fleets. CARB is currently (as of March 2008) considering rules that target most other in-use trucks in the state over 14,000 lb GVWR. As currently envisioned, the rules would be phased in to require that all truck engines meet the 2007 EPA standard by 2013, and all truck engines meet the 2010 EPA standard by 2021. Current plans call for the proposed rules to be presented to the Air Resources Board in mid-2008. CARB is also developing separate rules focused specifically on drayage trucks serving ports and intermodal yards.

If adopted, these proposed rules would modernize almost all remaining California-registered trucks in the SCAG region on a mandatory basis by 2020. While these rules may be modified before they are adopted, and they may also be challenged in court, it is likely that in-use truck rules will take effect in some form in the next five to ten years. In this event, the CARB rules would pre-empt most of the truck emission reduction strategies that otherwise could have been implemented for 2020 as part of a voluntary incentive program. For this reason, and in order to define programs that achieve benefits earlier than 2020, this Action Plan focuses on truck strategies for 2010 but not 2020. Recommended truck strategies for 2010 are discussed in Section 2.4. Implications of the CARB rules for strategy priorities are discussed further in Section 5.

The other major development is the **San Pedro Bay Ports Clean Truck Program**, part of the Ports' *Clean Air Action Plan* described in Section 1. Both Ports have approved a ban on older trucks, to be phased in beginning October 1, 2008 with a ban on all trucks built before 1989. By January 1, 2010, only trucks built after 1993 will be allowed to enter the Ports, and by January 1, 2012 all Port-serving trucks must meet 2007 U.S. EPA standards. The Ports recently approved a container fee of $35 per TEU in order to fund the Clean Truck Program; the funds will be used to replace or retrofit the existing fleet. Ultimately, the Ports hope to retrofit or replace nearly all of the 16,000-odd trucks that serve the Ports. These trucks represent approximately 40% of all the heavy heavy-duty diesel trucks registered in the South Coast Air Basin.

Several voluntary incentive programs are also helping to reduce truck emissions in the SCAG region:

- The **Carl Moyer Program** is a voluntary grant program to fund the incremental cost of cleaner-than-required heavy-duty engines, implemented as a partnership between CARB and the local air quality management districts. For nearly 10 years, the program has provided funding for truck replacement and repowering projects, as well as a large number of off-road emission reduction projects.
- The **Gateway Cities Council of Governments Clean Air Program** has a Fleet Modernization component intended to reduce emissions from port trucks. More than 75% of the funding to date for the program has been provided by the Port of Los Angeles. The program has resulted in the replacement of more than 600 trucks that operate in the vicinity of the Ports.

2.3. Contribution of Older Trucks to Emissions

While the new EPA standards will reduce future truck emissions in the region, the long lifetime of trucks delays these emissions benefits as owners only slowly replace older trucks with newer ones. Larger trucking companies engaged in long-haul transport typically replace their trucks every four to six years. But smaller fleets, and those engaged in local operation, may continue to operate trucks that are 15 to 20 years old. Table 2-2 illustrates how, in 2010, older trucks will contribute a disproportionately large share of emissions. For example, in 2010, heavy heavy-duty diesel trucks (HHDDTs) that are more than 12 years old (i.e., pre-1999 trucks) will be responsible for over 40% of NOx and PM2.5 while accounting for just 25% of the VMT from this segment of the truck population.

Table 2-2: VMT and Emissions Contributions of Older Heavy Heavy-Duty Diesel Trucks in 2010

HHDDT in SCAG Region	Truck Model Year				Contribution of Pre-1999 Trucks
	Pre-1999	1999-2006	2007+	All	
Truck Population	19,470	14,369	8,150	41,990	46%
VMT, mi/day	1,465,550	2,404,102	2,034,300	5,903,952	25%
NOx, tons/day	44.6	51.0	14.6	110.2	40%
PM2.5, tons/day	2.3	2.4	0.3	5.0	46%

Source: EMFAC 2007, California Air Resources Board

Several other factors should be considered when determining target populations to replace or retrofit. To get a better picture of what truck model years and weight classes are the best targets for reduction strategies, Table 2-3 shows the *per-truck* emissions contributions for heavy heavy-duty trucks in 2010.

Table 2-3: Per-Truck Annual VMT and Emissions for Heavy Heavy-Duty Diesel Trucks in 2010

	Truck Model Year		
Description	**Pre-1999**	**1999-2006**	**2007+**
VMT (miles/year per truck)	27,474	61,068	91,103
NOx (lbs/year per truck)	1,672	2,593	1,308
PM2.5 (lbs/year per truck)	84.6	121.8	27.0

Source: EMFAC 2007, California Air Resources Board

The highest emissions per truck occur for the 1999-2006 model years. In the year 2010, replacing just one 1999-2006 model year heavy heavy-duty truck with a 2007+ truck could reduce 1285 lbs of NOx and 95 lbs of PM2.5 per year. Because these are the highest emitters in terms of emissions per year, they are also the best target for emission reduction retrofits. Pre-1999 trucks emit more on a per-mile basis but travel fewer miles on average, so the net effect is lower annual emissions per truck than the 1999-2006 model year trucks.

2.4. Overview of Truck Emission Reduction Strategies

Available Strategies

A variety of strategies can reduce emissions from on-road trucks. Most such strategies can be grouped into the categories below. For further details on emission control strategies, see the accompanying *Analysis of Goods Movement Emission Reduction Strategies: Task 1 Final Report*, available at www.scag.ca.gov/goodsmove/pdf/AnalysisGoodsMovementEmission_FinalReport.pdf.

- **Accelerated Engine Controller Reprogramming ("Chip Reflash").** In the early 1990s, engine manufacturers began producing heavy-duty engines with engine control software that produced higher NOx emissions and better fuel economy when the truck was operating in a mode other than the emissions certification cycle (such as long periods of freeway driving). U.S. EPA and the engine manufacturers signed a Consent Decree that, among other provisions, requires engine manufacturers to remove the software when 1994-1998 engines are rebuilt. Accelerating the reprogramming of the engine controller will yield NOx benefits.
- **Replacement (Accelerated Turnover).** Replacing older trucks with newer, cleaner diesel trucks can reduce PM and NOx emissions significantly. This strategy can work well when directed at a specific truck population that tends to be older than average, such as port-serving trucks. Truck replacement strategies often have a high cost per truck but also produce large emission reductions.

- **Repowering.** By swapping an older existing diesel engine with a newer, cleaner diesel engine, significant NOx and PM emission reductions can be obtained at lower cost than replacing the entire truck. This is generally feasible for pre-1994 trucks and some 1994-2006 trucks, though case-by-case evaluation is necessary due to physical and cost constraints.

- **Retrofit.** Exhaust treatment devices often can be retrofitted to many existing trucks with only minor modifications to the exhaust system. The three main retrofit technologies currently in use for trucks are:

  - Diesel oxidation catalysts (DOCs)
  - Flow-through filters (FTFs), and
  - Diesel particulate filters (DPFs) with or without low-NOx catalysts (LNC).

  All of these retrofit devices provide substantial reductions in PM emissions. DOCs reduce PM emissions by more than 25%, FTFs reduce PM emissions more than 50%, and DPFs reduce PM emissions more than 85%. Systems with LNC also reduce NOx emissions by about 25%.

  DOCs and FTFs have the lowest initial cost of available retrofits but also the smallest PM emission reductions. These devices require minimal modification to the truck chassis and in many cases simply replace the truck's original muffler.

  DPFs are termed passive or active, depending on the method used to regenerate, or oxidize, the captured particulate matter. Passive and semi-active DPFs require operating temperatures above certain thresholds for a percentage of the operating time in order to regenerate. Fleets that are considering these devices must take into account the exhaust temperature variations generated by their trucks. The time/temperature requirements of passive DPFs limit the population of trucks that can accept these retrofits. Active DPF systems, which do not have this limitation, are available but cost significantly more than passive retrofit systems.

- **Combination Replace and Retrofit.** Replacement and retrofit can be combined when the replacement truck is of model year 2006 or earlier. A model year 2006 or earlier truck could replace an earlier truck, and the replacement truck could be retrofit with a DPF or DPF+LNC.

- **Alternative Fuels.** There are many alternative fuel options for trucks, although most are limited by supply issues and high cost. Biodiesel is readily available and, when blended at 20% (B20), requires no engine modification. Use of B20 reduces PM and ROG emissions by approximately 20%; it may slightly increase NOx emissions. Natural gas is widely used in heavy-duty applications (particularly transit buses and refuse trucks). Dedicated LNG trucks can be purchased new, resulting in 70-90% reductions in NOx and PM as compared to used (pre-2007) trucks.

- **Virtual Container Yard.** A virtual container yard is an internet-based system that facilitates coordination between shippers and receivers so that containers can be filled with export cargo before returning empty to the Ports. Matching empty containers with shippers can eliminate truck trips and associated emissions. It has been estimated that, currently, only about 2% of emptied import containers are matched with shippers needing an export container.[9] Increasing this percentage can be a cost-effective way to reduce truck trips and emissions, although the emissions benefits would be relatively small.

- **Incident Management for Trucks.** Clearing highway incidents more rapidly will reduce congestion and associated emissions. Most tow trucks used in conventional incident management programs are not capable of pulling heavy-duty trucks. In congested corridors with heavy truck volumes, a dedicated truck incident management program can be a cost-effective way to reduce emissions.

- **Infrastructure Projects.** Investments in highway infrastructure can potentially reduce truck emissions. One option proposed for the SCAG region is a system of dedicated lanes for clean technology trucks running from the Ports in the I-710 corridor, east-west to the Inland Empire, and north-south on the I-15 corridor. The emission impacts of such investments depend heavily on how they affect travel speeds and congestion.

Feasibility Issues

The feasibility of the potential truck emission reduction strategies varies with technical factors as well as economic and regulatory considerations. Table 2-4 summarizes feasibility issues associated with the potential strategies. In some ways, achieving emission reductions from on-road trucks is significantly more challenging than in the other goods movement sectors because ownership is dispersed across so many different entities. While locomotives, port equipment, and marine vessels are owned and operated by relatively few companies, there are tens of thousands of truck owners in the SCAG region. Some large carriers own and operate many trucks, but a large portion of the truck population is in the hands of independent owner-operators or small fleets.

Table 2-4. Summary of Feasibility Issues for Truck Strategies

Strategy	Technology/ Applicability	Cost [a]	Industry Acceptance	Other Potential Barriers
Chip Reflash	Affects 1994-1998 HHDDT engines that have not yet been rebuilt or had NOx software removed	Low (≈$500)	No significant barriers, but truck owners see no benefit	Benefits decrease over time as number of un-rebuilt engines dwindles. Most 1994-1998 engines should have been rebuilt by 2010. Minimal benefits by 2020.
Truck Replacement	For 2010: Replace MY 1994-1998 trucks with MY 2007+ trucks. Replace MY 1999-2006 trucks with MY 2007+ trucks. For 2020: Replace MY 1999-2006 trucks with MY 2010+ trucks.	High. Availability of affordable financing is a concern for owner-operators and smaller fleets.	Acceptance may vary with incentive levels and administrative/ paperwork burden. Truck owners who do their own maintenance may not participate, due to increased cost for professional maintenance.	Voluntary incentive programs require very large outreach and technical assistance efforts in order to achieve desired truck participation rates. Supply of recent model used trucks vs. high demand could be an issue for an aggressive replacement program. MY 1994-1998 trucks will have limited lifetime remaining by 2010 and may be replaced soon even without a new program.
Repowering	New engines are readily available. However, 2007+ engines are not compatible with pre-2007 truck chassis. Repowering a pre-1994 truck with 1994-2006 engine is sometimes feasible depending on engine compartment space constraints.	Medium cost for repowering 1994+ truck with pre-2007 engine. Cost of repowering pre-1994 truck with 1994+ engine (elect. fuel injection) may be excessive for remaining value of truck.	See above	Supply of recent model used engines vs. high demand could be an issue for an aggressive repowering program.

Strategy	Technology/ Applicability	Cost [a]	Industry Acceptance	Other Potential Barriers
Retrofit – DOC	Typically applicable to 1988-2002 engines.	Low ($1,200 - $2,000)	No significant barriers, but truck owners see no benefit	None
Retrofit – FTF	Typically applicable to 1991-2002 engines and some 2003-2006 engines.	Low ($2,750 – $4,500)	No significant barriers, but truck owners see no benefit	None
Retrofit – DPF	Typically applicable to 1994-2006 engines. Passive regeneration systems are not compatible with some duty cycles due to exhaust temperature requirements.	Low to Medium ($7,000 - $9,000). Active regeneration systems are at upper end of DPF cost range.	No significant barriers, but truck owners see no benefit	None
Retrofit – DPF+LNC	Typically applicable to 1993-2003 turbocharged engines. Compatible with fewer trucks than DPF due to chassis modifications required.	Medium ($25,000). Active regeneration systems are at upper end of DPF cost range.	No significant barriers, but truck owners see no benefit	None
Biodiesel	B20 requires no engine modification	Low (w/ federal tax credit, per gal. cost similar to diesel)	No significant barriers, although fuel quality may be a concern	May slightly increase NOx
LNG	New LNG trucks would replace pre-2007 trucks	High ($140,000 for new heavy heavy-duty LNG truck)	No significant barriers, although some may have performance concerns	Limited fueling infrastructure. Limited benefits compared to new 2010+ truck.
Virtual Container Yard	Reduces truck trips by matching empty containers with export shippers	Low	No significant barriers	Benefits are small
Incident Management for Trucks	Heavy tow truck freeway service patrol	Low	No significant barriers	Requires consistent funding program
Highway Infrastructure Projects	Dedicated truck lanes, possibly with tolls	High. Costs potentially could be offset through tolling and/or public-private partnerships.	High support for capacity improvements; mixed support for tolling	Potential local impacts

Note a: Where no cost figure is given, cost ranges are illustrative and per-truck costs may be interpreted as “low” = $100s to $1,000s, “medium” = $1,000s to $10,000s, and “high” = $10,000s to $100,000s.

The resources available to truck owner-operators and small fleets is another barrier to many of the strategies involving retrofits, replacement, repowering, and alternative fuels. Emission control retrofits do nothing to improve fuel economy (and may even slightly reduce fuel economy), so most truck owners will not perform retrofits unless they receive significant financial incentives or face a regulatory requirement. Biodiesel and some other alternative fuels face similar barriers. Even large incentives to replace older trucks with newer ones may be unattractive to owner-operators, particularly for truck owners who perform their own maintenance and lack the expertise and equipment to work on newer engines.

Another important issue to consider when considering emission reduction strategies for trucks is the operating range of the affected vehicle. Trucks that spend a significant portion of their time outside the South Coast Air Basin are not good candidates for retrofits, repowers, and replacements because much of the emissions benefit will occur outside the region.

Operational strategies to reduce truck travel or congestion (such as a virtual container yard or incident management for trucks) are generally popular with industry and relatively cost-effective. But the total emissions benefits from these types of strategies are small. Highway infrastructure projects can also potentially reduce truck emissions, depending on how they influence traffic speeds and congestion levels. Projects of this nature are being considered primarily to improve mobility and safety rather than to reduce emissions.

Participation Rates in Voluntary Incentive Programs

Many of the strategies described above could be implemented either through regulation or a voluntary incentive program. If a voluntary incentive approach is pursued, the emissions benefits vary directly with the number of trucks that participate in the program. The participation rate (or market penetration rate) is defined as the number of trucks replaced, repowered, retrofitted, etc. as a fraction of the total target population of trucks. Higher levels of funding can achieve greater participation by inducing a larger percentage of truck owners to participate. For lower rates of participation the program costs likely are scalable – the cost of achieving a 2% truck participation rate would be roughly twice the cost of achieving a 1% participation rate, the cost of achieving 3% is three times the cost for 1%, and so on. To achieve relatively high participation rates, the program cost is likely to be disproportionately higher because the most willing truck owners will already have participated and greater incentives are needed to induce the remaining owners to participate.

Participation rates in voluntary vehicle programs depend primarily on two factors:

- The value of the incentive (depth of subsidy) offered, and
- The intensity of the program's outreach effort toward potential participants (e.g., truck owners).

As the incentive value increases, so does the participation rate. Programs that offer 100% or greater grants (i.e., they covered all of the trucker's costs plus an additional incentive amount) have achieved the highest participation rates. The intensity of the outreach effort also strongly affects the participation rate. All else being equal, programs that used only public means to disseminate information — such as websites, requests for proposals, public workshops and meetings, and involvement of trade organizations — generally have lower participation rates than programs that used personal contact. The programs with the highest participation rates employed personal contact with each individual truck owner, as well as sustained follow-up and technical assistance.

Based on past experience, programs that offer a 100% subsidy level, use public outreach techniques, and use personal contact with technical assistance can perhaps achieve participation rates of 10%-15%. Achieving significantly higher participation would likely require a larger subsidy.

Summary of Cost Effective Strategies

Table 2-5 shows the most cost effective and feasible strategies for reducing truck emissions in 2010. Cost effectiveness has been calculated with the method used for the Carl Moyer Program, in which the numerator is annualized capital cost (ACC) and the denominator is the sum of ROG, NOx, and 20 times PM2.5 emissions.[10] The result is expressed as dollars per ton of (pollutant-weighted) emissions reduced.

As Table 2-5 shows, the largest per-truck emission reductions come from truck replacement, but these also carry the largest per-truck project cost. The second-largest truck emission reductions come from repowering 1999-2002 trucks with a 2003-2006 MY engine and retrofitting the new engine with a DPF. The applicable truck population in this case will be somewhat limited since DPFs require a duty cycle that provides enough exhaust heat to regenerate the filter. The next best emission reduction scenario is retrofitting 1999-2002 engines with a DPF and a lean NOx catalyst. Since the DPF+LNC option uses active regeneration (versus passive regeneration for standard DPFs), the duty cycle requirements are less limiting. Chassis space for the DPF+LNC is required, however.

DPFs alone provide a large PM and ROG benefit for 1994-2006 MY engines, but again, the population that can be retrofitted with DPFs is limited due to the duty cycle requirements needed to effectively regenerate the filters. Passive DPFs for 2003-2006 engines require more catalytic material and thus are more expensive. Diesel DOCs are the cheapest per-truck solution and they will work on any diesel engine built between 1994 and 2002. Many diesel engines built to meet the 2004 emission standards come with DOCs as original equipment. Finally, FTFs provide good emission reductions at a reasonable cost.

Table 2-5: Cost Effective Strategies for Heavy Heavy-Duty Trucks in 2010

HHDT Strategy	Model Year	Potential Truck Population	Lifetime Emission Benefits (tons/truck) NOx	PM2.5	ROG	Cost Per Truck	Weighted[a] Cost Effectiveness ($/ton)
Replace with 2007+ truck	1994-1998	9,708	10.78	0.44	1.15	$77,156	$3,709
	1999-2002	8,089	20.56	0.76	1.91	$77,156	$2,051
Retrofit with DOC	1994-1998	9,708	--	0.05	0.27	$2,000	$1,582
	1999-2002	8,089	--	0.12	0.65	$2,000	$640
Retrofit with FTF	1994-1998	9,708	--	0.10	0.40	$4,500	$1,878
	1999-2002	8,089	--	0.25	0.97	$4,500	$759
	2003-2006	6,281	--	0.36	0.48	$4,500	$581
Retrofit with DPF	1994-1998	9,708 [b]	--	0.17	0.48	$8,500	$2,194
	1999-2002	8,089 [b]	--	0.42	1.17	$8,500	$887
	2003-2006	6,281 [b]	--	0.62	0.57	$10,000	$773
Retrofit with DPF+LNC	1999-2002	8,089	3.76	0.42	1.17	$28,557	$2,140
Repower with 2003-2006 engine w/DPF	1999-2002	8,089 [b]	7.58	0.42	1.25	$40,000	$2,323

Note a: NOx + ROG + (20 x PM2.5)
Note b: Actual number of trucks that can be retrofitted with a passive DPF is smaller due to duty cycle requirements.

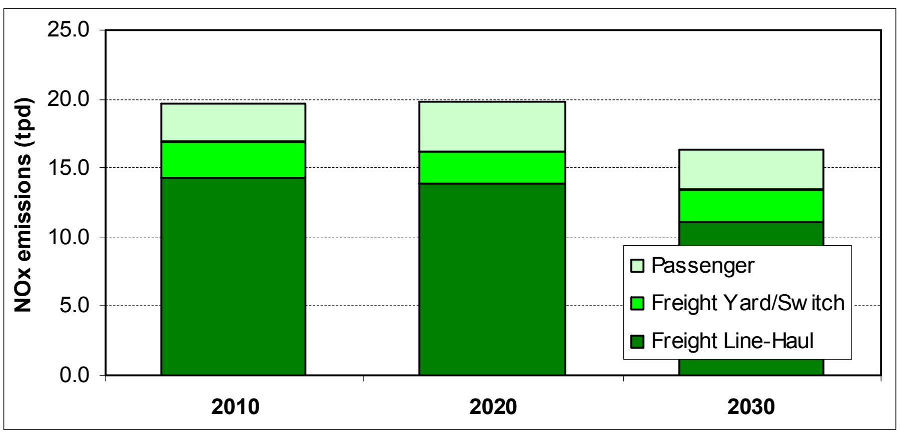
3. Rail Locomotive Strategies

3.1. Introduction

Railroad locomotives currently contribute 5-7% of goods movement emissions in the region. Freight rail locomotives are used in two primary ways: as a line-haul engine or as a switching engine. The line-haul engines function as the primary motive power for moving long-haul trains to and from Southern California. The switching engines are used for train building and general purposes within a rail yard, as well as to move local short-haul trains. Passenger train locomotives, such as those operated by AMTRAK and Metrolink, are not involved in goods movement but are often considered together with freight locomotives as part of the total regional railroad system.

Railroad locomotive emissions will total approximately 20 tons per day of NOx in 2010, as illustrated in Figure 3-1. Without any additional regulations or programs, locomotive emissions will remain fairly constant to 2020 and then begin to decline. Approximately 70% of the railroad NOx emissions come from line-haul freight locomotives.

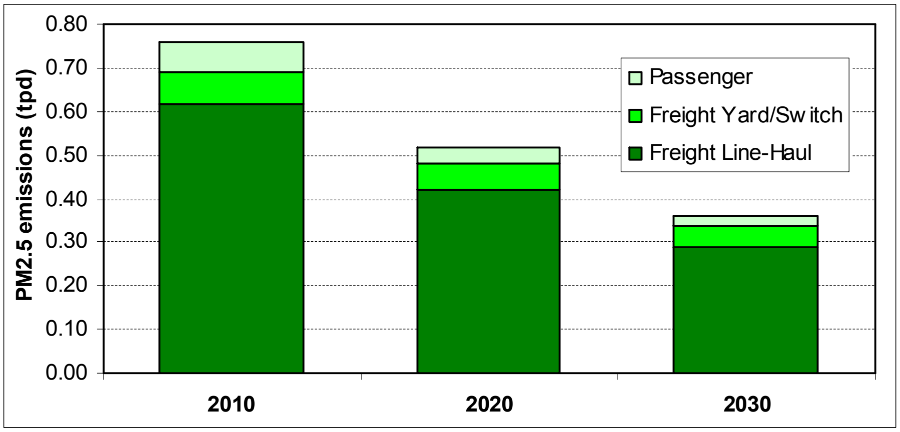
Figure 3-1: Baseline Railroad NOx Emissions in South Coast Air Basin



Source: California Air Resources Board, adjusted to reflect new EPA locomotive emission standards adopted March 14, 2008.

In terms of PM2.5 emissions, railroad locomotives will produce 0.76 tons per day in 2010, as shown in Figure 3-2. As a result of the new EPA standards, locomotive PM emissions will decline to approximately 0.5 tons per day by 2020. More than 80% of railroad PM emissions come from line-haul freight locomotives.

Figure 3-2: Baseline Railroad PM2.5 Emissions in South Coast Air Basin



Source: California Air Resources Board, adjusted to reflect new EPA locomotive emission standards adopted March 14, 2008.

3.2. Current Rules and Programs That Affect Locomotive Emissions

Since 2005, new locomotives have been required to meet U.S. EPA Tier 2 emission standards. NOx and PM emission rates under these standards are 45% - 60% lower than emission rates of uncontrolled locomotives. The Burlington Northern Santa Fe (BNSF) and Union Pacific (UP) railroads signed a Memorandum of Understanding with CARB that requires early introduction of Tier 2 locomotives into the South Coast Air Basin, such that both railroads must achieve a fleet average Tier 2 standard in the Basin by 2010.

The U.S. EPA adopted new emission standards for locomotives in March 2008.[11] The standards (shown in Table 3-1) include retrofits of existing equipment as well as new engine emission standards (Tier 3 and Tier 4). The Tier 4 standards are analogous to the 2007/2010 heavy-duty truck standards and will result in large reductions in NOx and PM emission rates – more than 90% lower than uncontrolled locomotives. The Tier 4 standards will likely require use of exhaust aftertreatment devices for the first time on locomotives. Existing engines will be subject to retrofit at the time they are rebuilt.

Table 3-1: Emission Standards for Locomotive Engines (g/hp-hr)

		Line Haul Engines		Switching Engines	
Emission Standard	Applicable Year	NOx	PM	NOx	PM
Uncontrolled Emissions		13.0	0.32	17.4	0.44
Tier 0 rebuild	2001	9.5	0.60	14.0	0.72
Tier 0 rebuild [a]	2008 / 2010	8.0	0.22	11.8	0.26
Tier 1	2002 – 2004	7.4	0.45	11.0	0.54
Tier 1 rebuild [a]	2008 / 2010	7.4	0.22	11.0	0.26
Tier 2	2005	5.5	0.20	8.1	0.24
Tier 2 rebuild [a]	2008 / 2013	5.5	0.10	8.1	0.13
Tier 3	2011 – 2012	5.5	0.10	5.0	0.10
Tier 4	2015	1.3	0.03	1.3	0.03

Note a: These are retrofit standards at the time of rebuild and phased in as retrofit kit availability allows.
Source: *Regulatory Impact Analysis: Control of Emissions of Air Pollution from Locomotive Engines and Marine Compression Ignition Engines Less than 30 Liters Per Cylinder.* EPA420-R-08-001. March 2008.

In addition to the EPA standards, several existing policies and programs will help to reduce locomotive emissions in the coming years.

- The Ports' *Clean Air Action Plan* includes three measures focused on rail locomotives. Measure RL1 will retrofit Pacific Harbor Lines (PHL) switch engines with 15-minute idling limit devices and diesel particulate filters. Measure RL2 will require that UP and BNSF switcher engines operating at the Ports use ultra-low sulfur fuel, be 90% controlled for NOx and PM, and be equipped with 15-minute idling limit devices. Measure RL3 will require that newly developed or significantly redesigned rail yards on Port property operate on the cleanest available technology for locomotives.
- In 2005, CARB established a Rail Yard Agreement with UP and BNSF that obligates the railroads to significantly reduce diesel emissions in and around rail yards throughout California. The agreement includes a statewide idling-reduction program and health risk assessments for all major rail yards. Under the agreement, the UP and BNSF have agreed to install idling reduction devices on their California-based locomotives.
- The Carl Moyer Program provides funding for the incremental cost of purchasing cleaner than required engines and equipment. Over the past four years, South Coast AQMD has awarded more than $13 million for rail locomotive projects in the region. These awards are being used to purchase cleaner new engines, retrofit existing engines, and install anti-idling devices on existing engines.

3.3. Overview of Locomotive Emission Control Strategies

Available Strategies

Strategies to reduce emissions from locomotives include retrofit controls, repowering and replacement with cleaner engine technologies, alternative fuels, idle reduction, electrification, and infrastructure projects to reduce train congestion.

- **Retrofits.** Exhaust treatment devices can potentially be retrofitted to existing locomotives, although barriers exist. Potential retrofit technologies include:
  - Diesel oxidation catalysts (DOCs) – DOCs reduce PM emissions by 25 to 40%; they do not affect NOx emissions. They have been used for more than 20 years and are perhaps the most proven after-treatment device for diesel engines, although there is little experience using them on locomotives. DOCs must be used with ultra-low sulfur diesel fuel, which will be required for all locomotives by 2010. There are several ongoing locomotive DOC testing and demonstration projects.
  - Diesel particulate filters (DPFs) – DPFs are the most effective PM retrofit device and, if functioning properly, can reduce PM emissions by 80 to 90%. Like DOCs, DPFs do not affect NOx emissions. As with trucks, DPFs on locomotives require the exhaust temperature be raised to a temperature sufficient to regenerate the DPF to prevent saturation and clogging, or else use active regeneration from an electric heating component. Long-term durability, performance, and maintenance requirements have yet to be established for DPFs on locomotives. There are also significant space constraints on locomotives, which the railroads regard as an additional limitation to installing DPF systems.
  - Selective catalytic reduction (SCR) – SCR has the potential to reduce NOx emissions by 75 to 90% but has a relatively small effect on PM emissions. SCR requires a reducing agent (ammonia or urea) to be injected into the exhaust stream to reduce NOx to N_2 and water. Because of the large volume of urea necessary, the space constraints on locomotives make this type of retrofit challenging. Like other devices, SCR systems on locomotives are still in the pilot project testing phase.

- **Hybrid and Gen Set Switching Locomotives.** Hybrid-electric locomotives (such as the "Green Goat") use a small, low-emission diesel engine to charge a battery pack that powers the traction motors. These engines can also recover braking energy to improve fuel efficiency. Generator set ("Gen Set") locomotives use a series of smaller diesel engines (each approximately 700 horsepower) to directly power the traction motors. One or two of the engines can be shut down in operations with lower power demand, saving fuel and reducing emissions.
- **Locomotive Repowering.** Locomotives can be repowered with newer engines that meet lower emission standards. For example, older Tier 0 locomotives can be repowered with engines that meet the new Tier 2 rebuild standards, providing a 40-80% reduction in NOx and PM emissions.
- **Accelerated Locomotive Rebuilds.** The new EPA emission standards include more stringent Tier 2 standards that apply upon normal rebuild of Tier 2 engines, resulting in significantly lower PM emissions for both line-haul and switching engines. The Tier 2 rebuild standards take effect beginning in 2008 as retrofit kits are available; they are required by 2013. Accelerating the rebuilding of Tier 2 engines, beyond what would occur due to normal rebuild frequency, would reduce PM emissions at a relatively low cost.
- **Accelerated Replacement with Tier 4 Engines.** As shown in Table 3-1, the new Tier 4 standards will result in emission rates that are 80-90% lower than current Tier 2 engines. Tier 4 engines will be required on new locomotives beginning in 2015. Accelerating the replacement of older locomotives with those meeting Tier 4 standards would produce large emissions benefits.
- **Idle Reduction.** There are a number of strategies to reduce idling times of locomotive line-haul and switching engines when there is no operational need for the engine to idle. These can involve operator training and use of technologies such as an auxiliary power unit (APU) or an automatic engine start-stop (AESS) device. The new EPA standards require idle reduction systems on newly manufactured locomotives.
- **Electrification.** Electrification of rail lines would involve installation of catenary power lines and use of electric locomotives to pull trains. Electrification could be done for the Alameda Corridor or, in theory, for the entire regional mainline railroad system.
- **Railroad Infrastructure Capacity Expansion.** Expanding railroad system capacity can reduce emissions by improving the efficiency of rail operations (e.g., smoother train flows) or by reducing truck VMT through expansion of on-dock and near-dock intermodal facilities.

Feasibility Issues

While there are many promising locomotive emission reduction options currently being evaluated, there is generally less experience with locomotive emission controls as compared to trucking. One reason for this is sheer numbers: the Class I railroads have approximately 22,000 locomotives in service, and new locomotive sales average about 780 units per year. In contrast, there are more than 2 million registered combination trucks in the U.S., and annual sales total more than 200,000. Naturally, potential manufacturers of emission reduction technologies may be reluctant to focus their attention on a relatively low volume market.

The lack of experience is particularly evident with locomotive aftertreatment controls. At the present time, neither CARB nor EPA have certified an emission control retrofit device for locomotives. Testing and improvement of locomotive retrofits is ongoing, however, including DOCs, DPFs, and SCR systems. Some of the technical challenges associated with locomotive retrofits are likely to be overcome in the coming years. However, the feasibility of emission control retrofits for locomotives is uncertain at the present time.

Another important feasibility consideration is area of operation. While switcher engines are typically confined to one location, line haul engines often pull trains across multiple states. If public agencies are considering funding emission reduction projects, they need to be assured that the benefits will occur locally. In Southern California, it may be possible for the railroads to dedicate specific line haul locomotives to operation in the SCAG region; such a possibility was considered during the development of the 1998 MOU between CARB and the Class I railroads. However, placing such constraints on the railroads may be disruptive to their operations, as trains entering or departing the region would need to change engines at the perimeter of the South Coast Air Basin.

There are few feasibility issues associated with locomotive repowering and replacement. With the adoption of the new EPA standards, accelerating the introduction of cleaner locomotives will be a reliable emission reduction strategy as soon as they become available. The major barriers involve cost. New switcher locomotives can cost $1.5 million, while new line haul locomotives can cost more than $2 million. Production volumes may also be an issue if the region pursues a rapid introduction of new locomotives. There are only two manufacturers of new line haul locomotives in the U.S., and together they produce less than 800 new engines per year for the entire nation.

Hybrid and Gen Set switcher locomotives are both currently in use in California. Both can result in significant fuel savings and therefore can be attractive to railroads in certain applications. Hybrid switchers cannot be used in applications with high power demand and flat terrain, and some have been recently been removed from service due to technical problems. Gen Set switchers are now used extensively by UP in California, with approximately 60 in operation in the SCAG region.

Idle reduction devices for locomotives are relatively new, but recently have been put to use in a number of locations, including the SCAG region. The automatic engine start-stop (AESS) device is a relatively low cost technology that is particularly well suited to use in the SCAG region. The major questions with this type of strategy concern the magnitude of potential benefits. The 2005 Rail Yard Agreement with CARB requires UP and BNSF to adopt idle reduction training programs and install idle reduction devices on their California engines. With this in place, it is not clear how much additional idle reduction benefit could be achieved through an additional government program.

Electrification appears to have great potential to reduce locomotive emissions, but there are uncertainties associated with the operational feasibility of this approach. There is no precedent for electrification of a freight rail system in the U.S. Electrification could practically be done only on railroad mainlines; the numerous track segments in switching yards and local rail spurs serving industry are too numerous to electrify and their low volume would not justify it. Thus, both diesel and electric locomotives would need to continue to operate in the region.

Where the electrified system begins, railroads would need to add electric locomotives to trains and possibly drop diesel electric locomotives, a process that could potentially disrupt service. Some have suggested use of “dual-mode” locomotives, which have the ability to operate solely on electricity when on track with wires and solely on diesel when outside the electric system. However, dual-mode locomotives are not currently produced with the high horsepower needed to move freight trains. In general, any significant deterioration of railroad operation and service due to electrification could result in a mode diversion of freight to trucks, which would offset some of the emissions benefits. Further research is needed to explore the feasibility of electrification.

Efforts to expand railroad infrastructure capacity face the challenges of high cost and potential local environmental impacts. Like all major infrastructure projects, these types of improvements would be accomplished through an extensive planning and environmental review process. Several such efforts are currently underway in the region. For example, the Port of Los Angeles is planning to add an on-dock rail facility in the TraPac terminal, which is the only container terminal currently without on-dock rail accessibility. The project is part of a terminal expansion that includes the update of 11 shipping berths as well as the addition of 67 acres. In December 2007, the Los Angeles Harbor Commissioners approved the TraPac container terminal expansion project. Another local project for rail infrastructure expansion is the Southern California International Gateway (SCIG), a near-dock intermodal rail facility to be constructed and operated by BNSF. The facility would be located north of Pacific Coast Highway, south of Sepulveda Boulevard, and west of SR-103, with easy access to the Alameda Corridor. The Port of Los Angeles is currently preparing SCIG's environmental impact report.

Table 3-2: Summary of Feasibility Issues for Locomotive Strategies

Strategy	Technology/ Applicability	Cost [a]	Industry Acceptance	Other Potential Barriers
Retrofit – DOC	For Tier 2 No verified device currently available	Uncertain; estimate $16,800 for switcher and $33,600 for line haul	Uncertain; no benefits to railroads	
Retrofit – DPF	For Tier 2 No verified device currently available	Uncertain; estimate $75,000 for switcher and $150,000 for line haul	Uncertain; no benefits to railroads	
Retrofit – SCR	For Tier 2 No verified device currently available	Uncertain; estimate $200,000 for switcher and $400,000 for line haul	Uncertain; no benefits to railroads	
Hybrid and Gen Set Locomotives	Replace Tier 0,1,2 Switchers	$750,000; avg. fuel savings of $23,000 per year	No major barriers; results in fuel savings	Not suitable for switch applications with high power requirements
Accelerated Rebuilds	Rebuild Tier 2 to new EPA standards	$9,000 - $34,000	No major barriers	Rebuild kits may not be available until 2013
Accelerated Replacement	Replace Tier 2 with Tier 4	$1.5 million for switcher; $2.4 million for line haul	No major barriers	Manufacturer production volumes are limited
Idle Reduction	AESS device	$11,500; fuel savings of $1,000 - $13,000	Potential concerns about feasibility	Additional benefits uncertain, on top of CARB 2005 MOU
Electrification	Alameda Corridor only, or entire regional mainline system	$6 - $8 billion for entire mainline system (incl. engines)	Opposed by railroads; concerns about effects on operations	
Railroad Infrastructure Projects	On-dock rail expansion Near-dock rail expansion E-W mainline expansion	$1 billion $200 million+ $2.5 billion+	High support for capacity improvements	Potential local impacts

Note a: Locomotive retrofit devices are not commercially available at present so costs are difficult to estimate. Future costs here are estimated based on the current per-horsepower cost of available retrofit devices for smaller non-road applications.

Summary of Cost Effective Strategies

Table 3-3 presents a summary of the locomotive strategies that are the most feasible, cost-effective, and have the potential to achieve significant emission reductions in 2020. The availability of retrofit kits for locomotives remains uncertain at this point; if they are available, these strategies would likely be the most cost-effective way to reduce locomotive emissions in 2020. Otherwise, replacing older locomotives with those meeting the Tier 4 standards (which will be available beginning in 2015) will be a reliable strategy for achieving large emission reductions at relatively low cost. Replacement of older switcher locomotives with hybrid or Gen Set engines can also have significant emissions benefits, and may be particularly attractive to railroads due to the fuel cost savings.

The new Tier 3 standards are identical to the Tier 2 rebuild standards for line-haul locomotives, so dedicating public funds to accelerate the introduction of new Tier 3 line-haul engines would not be recommended. For switch locomotives, Tier 3 locomotives are expected to have 25% lower NOx emissions than Tier 2 rebuilds. Nonetheless, because most Tier 2 engines are likely to be rebuilt by 2020 anyway, accelerating replacement with Tier 3 switchers would not be recommended.

Table 3-3: Cost Effective Strategies for Locomotives in 2020

		Lifetime Emissions Benefits (tons per locomotive)				
Strategy	**Type**	**NOx**	**PM2.5**	**ROG**	**Cost per Locomotive**	**Weighted Cost Effectiveness ($/ton)**
Retrofit with DOC	Line-haul	0	1.55	2.77	$33,600	$122
	Switch	0	0.17	0.39	$16,800	$552
Retrofit with DPF	Line-haul	0	3.38	3.86	$150,000	$259
	Switch	0	0.37	0.55	$75,000	$1,161
Retrofit with SCR	Line-haul	224.8	0	0	$400,000	$219
	Switch	22.0	0	0	$200,000	$1,122
Retrofit with DPF+SCR	Line-haul	224.8	3.38	3.86	$550,000	$229
	Switch	22.0	0.37	0.55	$275,000	$1,133
Replace Rebuilt Tier 2 with Tier 4	Line-haul	399.5	5.59	6.71	$2,400,000	$341
	Switch	42.2	0.68	0.95	$1,500,000	$1,946
Replace with Hybrid Switcher	Line-haul	N/A	N/A	N/A	N/A	N/A
	Switch	23.8	0.42	0.45	$750,000	$2,839

4. Strategies for Other Goods Movement Sources

Other major sources of goods movement emissions are ocean-going vessels, commercial harbor craft, and cargo handling equipment at ports and rail yards. Because these sources are being actively addressed by the Ports and CARB, and because SCAG does not (directly) plan for improvements to these elements of the region's goods movement system, this Action Plan does not suggest a program of recommended emission reduction strategies for these sources. This section presents a brief overview of the most promising strategies and discusses their feasibility.

4.1. Ocean-Going Vessel Strategies

Introduction

Ocean-going vessels (OGVs) are a large and growing source of NOx and PM emissions in the SCAG region. According to emission inventory data from SCAQMD and CARB, OGVs currently account for 13% of goods movement NOx emissions and 24% of goods movement PM2.5 emissions in the South Coast Air Basin. Because of the limited regulation on OGV emissions and the rapid growth in imported goods through Southern California ports, emissions from this sector are expected to grow significantly. Absent any new control strategies, by 2020, OGVs will account for 42% and 60% of goods movement NOx and PM2.5, respectively, in the South Coast Air Basin.

OGVs include containerships, tanker ships, bulk carriers, automobile carriers, general cargo ships, roll-on roll-off ships, and cruise ships. Container ships are responsible for approximately 61% of OGV NOx and PM emissions at the Ports of Long Angeles and Long Beach, followed by cruise ships (13%) and tankers (11%).[12] [13] OGV emissions come from both the ship propulsion and auxiliary engines, and from smaller sources such as on-board boilers or other combustion processes.

Current Rules and Programs that Affect OGV Emissions

Emission standards for OGVs are generally regulated by the International Maritime Organization (IMO). Approximately 95% of the OGVs calling on US ports are foreign flag, and the U.S. has no authority to set emission standards for foreign flag vessels. However, CARB and EPA can potentially set requirements on ships that call at U.S. ports, such as fuel requirements.

- CARB's Auxiliary Engine Rule requires ships to use fuel with lower sulfur levels in their auxiliary engines within 24 nautical miles of shore. Prior to this rule, most ships used 2.5% sulfur residual oil in their auxiliary engines. As of January 1, 2007 the rule requires use of 0.5% sulfur fuel in auxiliary engines, with the standard reduced to 0.1% sulfur fuel in 2010. The rule is currently being challenged in court. If upheld, the effect of this rule will be to lower PM and sulfur oxide (SOx) emissions from OGVs in the vicinity of the San Pedro Bay Ports. In addition, by lowering fuel sulfur levels, exhaust aftertreatment such as catalysts and particulate filters can be used more efficiently.

- CARB currently is developing a regulation to reduce emissions from OGV main engines through use of lower sulfur fuels. CARB also is developing shore power requirements for ship and commercial harbor craft, and recently adopted regulations for ship onboard incineration.

- On March 14, 2008, U.S. EPA issued a final rule on new emission standards for locomotives and marine engines.[14] The standards require emission controls on new and remanufactured marine engines with per-cylinder displacement below 30 liters per cylinder (Categories 1 and 2 marine engines). OGV auxiliary engines and harbor craft main engines typically are of this size. The EPA projects that the standards will achieve large reductions in NOx and PM through the use of technologies such as in-cylinder controls, exhaust aftertreatment, and low-sulfur fuel, starting as early as 2011. As noted above, since most ships calling on California ports are foreign flag, these regulations would have to be adopted by the IMO in order to have any practical effect on emissions from OGVs.

- While still in the discussion stage, U.S. EPA is considering proposing NOx standards on marine engines with per-cylinder displacement at or above 30 liters per cylinder (Category 3 marine engines). OGV main engines typically are of this size. The potential standards for Category 3 marine engines which provide further reductions upon the Tier 1 IMO Annex VI standards. As with the EPA March 2008 rule, these regulations would have to be adopted by the IMO in order to have any practical effect on emissions from OGVs.
- U.S. EPA is also considering assigning the entire U.S. as a sulfur emission control area (SECA). Initial thoughts were to require fuel sulfur levels of 1.5% or less, however, consideration is being given to much lower levels. The control area distance from shore is also under discussion.

Without further reductions, like the ones above and those suggested below, OGV emissions of NOx, PM2.5, and SOx will more than double by 2020.

Vessel Speed Reduction

Description: OGV activity in the vicinity of a port is often classified into four distinct operating modes: *cruise* (beyond 20 nautical miles outside of the breakwater), *reduced speed zone* (within 20 nautical miles of the breakwater), *maneuvering* (between the breakwater and the dock), and *hotelling* (time spent at dock or anchorage). Under a vessel speed reduction program, the reduced speed zone is extended further into the cruise region, which slows ships earlier in their approach to the port. Because engine load, and thus emissions (NOx in particular) increase with vessel speed, slower speeds usually result in lower main engine emissions. The Ports have enacted a voluntary vessel speed reduction program, and intend to implement a mandatory plan as part of the CAAP, that would expand the vessel speed reduction from the current 20 nautical miles offshore to 40 nautical miles.

Feasibility: While this is a relatively easy strategy to implement, there is some resistance from shipping lines due to the increased time needed to enter and leave the port. Some shippers have indicated that they might increase speed outside the VSP zone to make up the lost time, which would offset some of the emission reductions. Enforcement may also be an issue.

OGV Shore Power (Cold Ironing)

Description: Approximately 40-50% of OGV emissions at the Ports occurs while the vessels are at berth. [15] [16] Emissions from vessels at berth can be reduced by providing shore power. Cold ironing enables ships to shut down their auxiliary engines and run off the shore-side electrical power grid to supply power at the dock for refrigeration, lighting, climate control, and other needs. To support shore power, the port or terminal operator must install necessary shore-side infrastructure, and ship owners must retrofit their ships to accommodate shore power through a connection interface with the ship's main electrical panel. Both San Pedro Bay Ports have committed to employ shore power and expand the necessary infrastructure.

Feasibility: The main issue with cold ironing is cost. Ship retrofits to accommodate cold ironing range from $500,000 to $1,000,000 per ship depending upon the voltage requirements. Around 90% of all container ships visiting California use 440V power, which would necessitate use of a transformer and thus raise costs per ship. The shore side costs depend heavily on the availability of infrastructure and can cost from $1,000,000 to $7,000,000 per berth. In addition, depending upon electricity rates, the cost difference between electricity and diesel fuel can be significant. Cold ironing is most cost effective for ships that dock frequently at the same terminal.

Expanded Auxiliary Engine Fuel Requirements

Description: Auxiliary engines are responsible for a roughly half of OGV emissions in the region.[17] [18] Most vessels currently use high sulfur residual oil bunker fuel in their auxiliary engines, which typically has 2.5% sulfur content. CARB's Auxiliary Engine Rule mandates that, starting in 2010, fuel with a sulfur content of 0.1% or less must be used in auxiliary engines within 20 nautical miles of the Ports. Additional emission reductions could be achieved by extending that requirement to cover the 40 nm expanded reduced speed zone, rather than the 20 mile zone specified in the CARB Rule.

Feasibility: There are minimal technological barriers to this strategy. Almost all ships have more than one fuel tank allowing storage of both residual oil (RO) and lower sulfur marine gas oil (MGO). A mixing tank is used to transition the ship engine from one fuel to the other to prevent problems while approaching a port. The main feasibility issue is that MGO costs more than twice as much as RO. There are also potentially challenging issues regarding enforcement. Ensuring compliance with this measure would rely on record keeping and random fuel testing.

Main Engine Fuel Requirements

Description: Main engines on OGVs are responsible for 45-50% of total OGV emissions at the San Pedro Bay Ports. As with auxiliary engines, OGVs could replace the high-sulfur RO used in main engines with lower sulfur MGO to reduce direct emissions of PM and SOx. Because of the high sulfur fuel typically used in main engines, the emissions savings from main engine fuel switching would be quite large. CARB is currently considering a main engine fuel requirement for California ports, and US EPA is considering a national rule. One option would be to require all vessels calling on the San Pedro Bay Ports to switch to 0.2% sulfur MGO when operating in the vessel speed reduction zone.

Feasibility: There are number of implementation barriers to be resolved in order to implement fuel switching for main engines. The availability and cost of low sulfur fuel is the primary barrier to use of reduced sulfur fuels in main engines. There are also concerns over maintaining adequate engine lubrication, filter clogging, increased cylinder wear, and safety issues due to flash-point differences. Maintaining different fuels at their appropriate temperatures might also prove challenging, and there are concerns that some ships may not be able to take on enough low-sulfur fuel to power the main and auxiliary engines from 40 nm to the berth.

Engine Improvements

Description: Emissions from existing OGV engines could be reduced through a variety of retrofit technologies, including slide-valve fuel injection and other internal modifications, exhaust aftertreatment technologies such as selective catalytic reduction (SCR) and exhaust gas recirculation (EGR), and other control technologies. The Ports have created a Technology Advancement Program (TAP) to evaluate promising technologies. To date, the only technology approved by the TAP is slide-valve injectors for main engines. According to one recent study[19], slide valve retrofits are simple to undertake on older engines that were not manufactured with such technology; most newer engines (approximately model year 2000 and later) are manufactured with slide-valve injectors. The Ports estimate the emission reduction potential from slide valve injectors to be 30% of main engine NOx emissions and 25% of main engine PM emissions.

Feasibility: Most retrofits require significant modification of the engine or exhaust system. Slide valves are currently limited to engines manufactured by MAN AG, but this retrofit is fairly straightforward. SCR requires significant deck space for the catalytic unit as well as storage of urea. As with locomotives, SCR for marine vessels is still in testing with a number of technological barriers to be resolved.

Crane Double-Cycling

Description: Crane double-cycling is a technique that enables the conversion of empty crane moves into productive ones. In a traditional crane movement, unloading and loading of containers happen in different stages, so cranes are empty approximately half the time. In double-cycling, loading and unloading happen concurrently, with cranes always utilized. Double-cycling can reduce operating times by 10%, improving the productivity of vessels, cranes, and berths. It can also reduce the requirements for yard tractors and drivers by 20%.

Feasibility: While this strategy appears to be feasible from a technological standpoint, it introduces major operational challenges including different operational procedures, training, new container handling equipment, and adjustments to how containers are stored and moved within the terminals. It also requires operational changes at export ports (e.g., Asian ports) since containers need to be positioned inside the vessel in a way that enables double cycling to operate.

Summary

Table 4-1 summarizes the major emission reduction strategies for OGVs and their barriers.

Table 4-1: Summary of OGV Emission Reduction Strategies

OGV Strategy	Potential Emission Reductions	Major Barriers
Expanded Vessel Speed Reduction	Large NOx	• Enforcement
Cold Ironing	Large NOx and PM	• High cost • Impractical for infrequent callers
Expanded Aux Engine Fuel Requirements	Medium PM and SOx	• Higher fuel costs
Main Engine Fuel Requirements	Large PM and SOx	• Higher fuel costs • Lubrication and other engine issues
Engine Improvements – Slide Valve Injectors	Large NOx and PM	• Limited to MAN engines built before 2000
Engine Improvements – SCR or EGR	Large NOx	• No retrofit devices verified by EPA or CARB • Deck space requirements for SCR • Engine modifications can be extensive
Crane Double-Cycling	NOx and PM	• Requires major operational changes • Requires participation by ports loading ships (Asian ports)

4.2. Harbor Craft Strategies

Introduction

Commercial harbor craft include a wide variety of vessel types: tugboats, ferries, small excursion craft, supply vessels (for off-shore service, cable laying, etc.), dredges, and service vessels such as fire, police, pilot, and commercial fishing boats. Harbor craft are U.S.-flagged vessels and, therefore, the engines used on the vessels fall under the regulatory authority of EPA and CARB. According to emission inventory data from SCAQMD and CARB, harbor craft are currently responsible for approximately 7% of NOx and PM2.5 emissions from goods movement in the South Coast Air Basin. Emissions from this source category are expected to decline because of federal and state regulations that will reduce emissions from harbor craft (see description of these regulations below). By 2020, harbor craft will account for approximately 6% of goods movement NOx and 5% of PM2.5 emissions.

Harbor craft are typically powered by smaller diesel engines and use a lower sulfur fuel than large OGVs. According to the latest emissions inventories from the Ports of Los Angeles and Long Beach, tugboats are responsible for approximately 57% of all NOx and PM emissions from harbor craft, followed by ferries (18%) and excursion boats (11%).[20] [21]

The strategies for harbor craft emission control include many of the same measures used for OGVs: lower emitting engines, cleaner fuels, after-treatment controls, and shoreside power. To date, some of these strategies have been implemented using Carl Moyer, AQMD, port, and other funds.

Current Rules and Programs that Affect Harbor Craft Emissions

- The U.S. EPA has regulated emissions from harbor craft engines through its Tier 1 standards and the more stringent Tier 2 standards, which phased in from 2004 through 2007. EPA recently adopted new Tier 3 and 4 emission standards for category 1 and 2 commercial marine engines (which apply to all harbor craft). The new Tier 3 standards take effect beginning in 2013 and require NOx and PM emission reductions of 28% and 66%, respectively, compared to the current Tier 2 standards. Tier 4 standards take effect beginning in 2016 and require NOx and PM emission reductions of 84% and 91%, respectively, compared to the current Tier 2 standards.
- Beginning in 2006, CARB requires harbor craft in the South Coast Air Basin to use on-road diesel fuel (i.e., ultra low sulfur diesel fuel). With a maximum 15 parts per million sulfur, this fuel has far lower sulfur content than marine engine fuels, which reduces PM and NOx emissions and enables use of exhaust retrofits such as diesel particulate filters.
- CARB has proposed regulations for existing (in-use) commercial harbor craft. As currently envisioned, these regulations would require that (1) engines acquired for in-use vessels must meet most current EPA engine standards, and (2) older engines be replaced with new certified engines meeting EPA Tier 2 or 3 standards, or must use aftertreatment. The compliance schedule would be phased in from 2009 to 2022, targeting the oldest and highest-use engines first.

Cleaner Fuels for Harbor Craft – Biodiesel

Description: This strategy would involve substituting biodiesel fuel for conventional diesel in harbor craft propulsion and auxiliary engines. Biodiesel fuels are derived from a variety of renewable sources such as vegetable oil, animal fat and cooking oil, and are used alone or blended with diesel fuel. Most diesel engines can operate using a blend of 20% biodiesel (B20) without modification. The use of biodiesel will reduce emissions of sulfur oxides, PM, and ROG, although NOx emissions may increase slightly. These effects tend to increase as the percent of biodiesel in the fuel increases.

Feasibility: There are no major barriers to using B20 in harbor craft engines. Commercial biodiesel is readily available in various blends. Because of a federal tax credit, the price of biodiesel is on par with conventional diesel. Using higher blends of biodiesel would likely require some engine modifications. Because of the potential for higher NOx emissions, this strategy would require further research.

Retrofit Harbor Craft with Emission Controls

Description: This strategy would retrofit the existing Category 1 and 2 engines on harbor craft with emission control devices. Available technologies include diesel oxidation catalysts (DOC), which reduce PM and VOC emissions; diesel particulate filters (DPF), which remove a significant portion of the PM emissions from the exhaust stream, and can be used in combination with low NOx catalysts (LNC); and selective catalytic reduction (SCR) systems, which reduce NOx emissions. DPF systems require the use of ultra low sulfur diesel fuel. Many of these devices could also be combined for increased or multipollutant reductions.

Feasibility: The use of exhaust control retrofits on harbor craft has not been thoroughly tested and a number of technological barriers remain. There currently are no EPA or CARB verified retrofit devices for use in harbor craft. At the moment, it is not clear whether these devices can be applied practically to engines in harbor craft service. Because Category 2 engines are generally large, they would require large DPF or DOC systems which may exceed engine room capacity. In addition, systems large enough for Category 2 marine vessels are not currently produced "off-the-shelf". SCR systems require both space for the catalytic equipment plus storage of urea. LNCs require fuel sprayed in to the exhaust and could be considered a fire hazard by the Coast Guard. DOCs and DPFs also might be considered fire hazards by the Coast Guard.

Harbor Craft Repowering

Description: This strategy could take two forms. First, it could consist of replacement or rebuilding of existing harbor craft propulsion engines to meet Federal and State emission standards before the deadlines set by Federal and State requirements. This would be analogous to the fleet modernization programs discussed for trucks in Section 2. Second, the measure could consist of repowering with engines whose emissions are significantly lower than Federal and State requirements. In that case, there would be a decrease in emissions below regulatory requirements. Of the approximately 400 harbor craft at the Port of Los Angeles, about 38% have been repowered with cleaner engines through funding mechanisms such as the Carl Moyer program, demonstrating the feasibility of emissions reduction at the Ports through repowering vessels.

Feasibility: This approach is the preferred option identified by CARB in the proposed in-use harbor craft regulations. Generally, Tier 2 or 3 engines are smaller than Tier 0 or 1 engines, thus engine room capacity should be no problem. However, to replace an engine, the deck will normally need to be cut to allow removal and reinstallation of the engine. Engine replacements must be reviewed by the Coast Guard and 2-3 weeks of downtime per engine must be scheduled. Furthermore, different gearing may be required.

Shore Power for Harbor Craft

Description: Like OGVs, harbor craft at the Ports of Los Angeles and Long Beach could use shore power instead of auxiliary engines when tied up at their home facilities and awaiting their next assignment. For tugboats, implementation of tug shore power would occur at three locations: the Crowley home-port location next to the Port of Los Angeles fireboat facility, Millennium's home location at the end of Timm Way, and Foss Maritime's home location on Pier D in Long Beach. This strategy is consistent with the shore power component of the Ports' *Clean Air Action Plan*.

Feasibility: As with OGVs, implementation of this strategy would require the installation of necessary shore-side infrastructure, and tugboat owners must retrofit their vessels to accommodate shore power. Cost is the primary barrier to implementation. Use of shore power for harbor craft is likely to be less cost-effective than shore power for OGVs that call frequently.

Summary

Table 4-2 summarizes the major emission reduction strategies for harbor craft and their barriers.

Table 4-2: Summary of Harbor Craft Emission Reduction Strategies

Harbor Craft Strategy	Potential Emission Reductions	Major Barriers
Cleaner Fuels for Harbor Craft – Biodiesel	Small PM	• May increase NOx
Retrofit Harbor Craft with Emission Controls	Potentially large NOx and PM	• Generally not off-the-shelf • No retrofit devices verified by EPA or CARB
Harbor Craft Repowering	Potentially large NOx and PM	• Downtime • Coast Guard approval needed
Shore Power for Harbor Craft	Large NOx and PM	• High cost

4.3. Cargo Handling Equipment Strategies

Introduction

Cargo handling equipment (CHE) at ports and rail yards include yard tractors, cranes, forklifts, container handlers (e.g., top picks and side picks), and bulk handling equipment such as tractors, loaders, dozers, excavators, and backhoes. CHE contributes a relatively small fraction of total goods movement emissions in the region – approximately 3% of goods movement NOx and PM emissions currently, declining to just 1-2% by 2020.

Yard tractors are the most common type of cargo handling equipment at the Ports and account for approximately 60% of CHE NOx and PM emissions. Container handlers and cranes are each responsible for about 13% of port CHE emissions.[22] [23]

Current Rules and Programs that Affect CHE Emissions

- In 2004, EPA set new emission standards (Tier 4) for non-road engines that include most CHE, to be phased in primarily from 2011 through 2015. These standards are analogous in stringency to the 2007/2010 emissions standards for on-road trucks.
- In December 2005, CARB adopted a regulation that requires the replacement or retrofit of existing CHE engines with ones that use the cleanest available verified diesel emission control (VDEC). This rule will, in effect, modernize the existing fleet to meet the MY 2007 on-road diesel engine emission standards or the Tier 4 non-road standards. The CARB phase-in schedule began in December 2007. The rule also requires that new CHE meet the MY 2007 or later on-road diesel engine emission standards, Tier 4 non-road standards, or the equivalent by using a VDEC if Tier 4 does not apply, effective in 2007.
- The CAAP would require that by 2010, all yard tractors operating at the Ports must have the cleanest engines meeting 2007 on-road emission standards or Tier 4 non-road engine standards. The CAAP also requires all remaining CHE with diesel engines less than 750 hp to meet the 2007 on-road standards or Tier 4 standards by 2012. All remaining CHE with engines greater than 750 hp must meet Tier 4 standards by 2014 and prior to that, must be equipped with the cleanest available VDEC.

- For a number of years, the Ports of Los Angeles and Long Beach have had programs to reduce CHE emissions using replacement, retrofits, and alternative fuels. Funding for these programs has come from the Ports themselves, CARB, and other sources.

CHE Emission Reduction Strategies

Emission reduction strategies for CHE are similar to those for on-road trucks. They include:

- Replacing older equipment with CHE that meets more stringent emission standards (e.g., 2010 on-road truck standards for yard trucks and Tier 4 non-road standards for container handling equipment, cranes, and forklifts)
- Use of alternative fuels (e.g., LNG or LPG) in yard trucks and forklifts, and electrification of cranes and forklifts
- Retrofits of CHE with NOx control devices such as lean NOx catalysts or selective catalytic reduction.

By 2020, as a result of the regulations and the CAAP described above, CHE fleet will be mostly modernized, and even the oldest remaining CHE will meet the on-road MY2007 or non-road Tier 4 emission standards. Very little additional emission reduction will be feasible for the CHE fleet in 2020. Opportunities for further reductions of CHE emissions will be limited to accelerating compliance with EPA and CARB regulations between 2008 and 2020. Because the potential strategies that are cost effective would yield very little additional emission reduction by 2020, available funds should be targeted at other sources of goods movement emissions.

5. Summary and Recommendations

5.1. Implications of Other Agency Actions

As this document shows, numerous strategies are available to reduce goods movement emissions. The challenge for public agencies is to maximize the benefit of government resources dedicated to goods movement environmental mitigation. Strategies that can achieve this objective are those that:

1. Can achieve large emission reductions
2. Are relatively cost effective
3. Do not face major implementation barriers
4. Are unlikely to occur absent additional government support

The last point is particularly important, given the continuing evolution of ever-stricter emission control requirements. As discussed in Section 2, the CARB in-use truck rule and the Ports' Clean Truck Program will likely speed the modernization of the SCAG region's truck fleet on a mandatory basis, essentially pre-empting most current truck emission reduction strategies by 2020. Thus, additional public support for truck emission reductions should focus on the near term.

In contrast to trucks, the most effective emission reduction strategies for locomotives are not likely to be available for the next five to seven years. The new EPA locomotive standards mandate the modernization of the region's locomotive fleet but, unlike the CARB and Ports' truck programs, EPA intends the locomotive standards to be technology-forcing. The technologies that will be needed for locomotives to meet the new standards are still under development. Locomotive retrofit devices are not currently available and are unlikely to be available as commercial products by 2010. Tier 2 rebuild kits are not required until 2013, and Tier 4 engines will not be commercially available until 2015. By 2020, however, emission control technologies for locomotives will have been commercialized, and Tier 4 engines and retrofit kits are expected to be available.

Table 5-1 summarizes the cost effectiveness of the most effective truck and rail emission reduction strategies. The shading indicates how the selection of feasible and cost-effective strategies divides clearly between trucks in 2010 and locomotives in 2020. The recommended strategies for 2010 and 2020 are discussed in Sections 5.2 and 5.3 respectively.

Other major sources of goods movement emissions are ocean-going vessels, commercial harbor craft, and cargo handling equipment at ports and rail yards. As noted previously, this Action Plan does not include a program of recommended emission reduction strategies for these sources because the Ports and CARB are actively addressing these sources, and because SCAG does not (directly) plan for improvements to these elements of the region's goods movement system. Moreover, many of the potential emission reduction strategies face major technical and institutional barriers that have to be overcome to implement a feasible and cost-effective program for these sources.

Table 5-1: Summary of Most Effective Emission Reduction Strategies

Mode	Strategy Description	Truck Model Year or Locomotive Type	Weighted Cost Effectiveness ($/ton) 2010	2020
Truck	Retrofit with FTF	2003-2006	$581	Pre-empted by CARB Rules
Truck	Retrofit with DOC	1999-2002	$640	Pre-empted by CARB Rules
Truck	Retrofit with FTF	1999-2002	$759	Pre-empted by CARB Rules
Truck	Retrofit with DPF	2003-2006	$773	Pre-empted by CARB Rules
Truck	Retrofit with DPF	1999-2002	$887	Pre-empted by CARB Rules
Truck	Retrofit with DOC	1994-1998	$1,582	Pre-empted by CARB Rules
Truck	Retrofit with FTF	1994-1998	$1,878	Pre-empted by CARB Rules
Truck	Replace with 2007+ truck	1999-2002	$2,051	Pre-empted by CARB Rules
Truck	Retrofit with LNC+DPF	1999-2002	$2,140	Pre-empted by CARB Rules
Truck	Retrofit with DPF	1994-1998	$2,194	Pre-empted by CARB Rules
Truck	Repower with 2003-2006 engine w/DPF	1999-2002	$2,323	Pre-empted by CARB Rules
Truck	Replace with 2007+ truck	1994-1998	$3,709	Pre-empted by CARB Rules
Truck	Replace with 2010+ Model Year Truck	1994-1998	Not cost effective	Pre-empted by CARB Rules
Truck	Replace with 2010+ Model Year Truck	1999-2002	Not cost effective	Pre-empted by CARB Rules
Truck	Replace with 2010+ Model Year Truck	2003-2006	Not cost effective	Pre-empted by CARB Rules
Truck	Replace with 2010+ Model Year Truck	2007-2009	Not cost effective	Pre-empted by CARB Rules
Rail	Retrofit with DOC	Line-haul	Technology in development	$122
Rail	Retrofit with SCR	Line-haul	Technology in development	$219
Rail	Retrofit with DPF+SCR	Line-haul	Technology in development	$229
Rail	Retrofit with DPF	Line-haul	Technology in development	$259
Rail	Replace Rebuilt Tier 2 with Tier 4	Line-haul	Tier 4 engines not available until 2015	$341
Rail	Retrofit with DOC	Switch	Technology in development	$552
Rail	Retrofit with SCR	Switch	Technology in development	$1,122
Rail	Retrofit with DPF+SCR	Switch	Technology in development	$1,133
Rail	Retrofit with DPF	Switch	Technology in development	$1,161
Rail	Replace Rebuilt Tier 2 with Tier 4	Switch	Tier 4 engines not available until 2015	$1,946
Rail	Replace with Hybrid Switcher	Switch	Available (not quantified)	$2,839

5.2. Priorities for 2010

In order to illustrate potential strategy priorities for 2010 and the level of emission reduction that could be achieved for a given level of public investment, this section presents three hypothetical programs of on-road heavy-duty truck strategies. In all three programs, the objective is to obtain the largest emission reduction benefit. To construct these programs, funds were allocated to each selected truck strategy up to a target participation level until the maximum funding level was reached.

The first program assumes a funding level of $30 million. Because of the high cost of truck replacement, this program focuses on repowering as the most effective option. In this strategy, 6.65% of 1999-2002 model year trucks are repowered with 2003-2006 engines and retrofitted with a DPF. In order to obtain additional PM benefits, DPFs were targeted at 6.45% of the 1999-2006 model year trucks. Trucks built before 1999 are considered to have too little remaining life and their VMT and emissions contributions would be small. In total, the program would repower 538 trucks and retrofit 927 trucks, resulting in annual emission reductions of 408 tons of NOx, 70 tons of PM2.5, and 151 tons of ROG in 2010. The program details are shown in Table 5-2.

The overall participation rate assumed for Program 1 is about 13% for the 1999-2002 model year fleet and 6.5% for the 2003-2006 fleet. This is a reasonable participation rate that should be achievable with the assumed grant amounts with some limited outreach efforts.

Table 5-2: Program 1 with $30 Million Funding in 2010

HHDT Strategy	Target Model Year	Potential Truck Population	Assumed Market Penetration	Emission Reduction Benefits (tons/year)			Total Cost (million)
				NOx	PM2.5	ROG	
Repower with 2003-2006 Engine with DPF	1999-2002	8,089	6.65%	408	23	67	$21.5
Retrofit with DPF	1999-2002	8,089	6.45%	--	22	61	$4.4
	2003-2006	6,281	6.45%	--	25	23	$4.1
Total		14,369	10.2%	408	70	151	$30.0

The second program assumes a funding level of $100 million. In this program, truck replacement is targeted first, followed by repowering, because these strategies provide the largest emission reductions per truck. Replacement of the 1999-2002 model year trucks with 2007+ model year trucks provide the largest benefit, so these are targeted at 10% participation. The next largest reductions come from repowering 1999-2002 model year trucks with 2003-2006 model year engines and retrofitting them with a DPF. This is also targeted at 10% of the 1999-2002 model year fleet. The additional resources are allocated to reduce PM emissions from the remaining 1999-2002 fleet and also reduce PM emissions from the 2003-2006 fleet, assuming 4% participation. The program details are shown in Table 5-3.

In total, the program would replace 809 trucks, repower 809 trucks with newer engines and DPFs, and retrofit an additional 575 trucks with DPFs. The participation rate assumed for Program 2 is about 24% for the 1999-2002 model year fleet and 4% for the 2003-2006 model year fleet. This is a more aggressive participation rate that would require a fairly intensive outreach effort to achieve. The program removes 2,276 tons of NOx, 124 tons of PM2.5, and 308 tons of ROG each year.

Table 5-3: Program 2 with $100 Million Funding in 2010

HHDT Strategy	Target Model Year	Potential Truck Population	Assumed Market Penetration	Emission Reduction Benefits (tons/year)			Total Cost (million)
				NOx	PM2.5	ROG	
Replace with 2007+ truck	1999-2002	8,089	10.0%	1,663	61	154	$62.4
Repower with 2003-2006 Engine with DPF	1999-2002	8,089	10.0%	613	34	101	$32.3
Retrofit with DPF	1999-2002	8,089	4.0%	--	14	38	$2.8
	2003-2006	6,281	4.0%	--	16	14	$2.5
Total		14,369	15.3%	2,276	124	308	$100.0

The third program assumes a funding level of $300 million. In this program, truck replacement is targeted first, followed by repowering. Replacement of the 1994-1998 and 1999-2002 model year trucks with 2007+ model year trucks provides the largest benefit, so these are each targeted at 20% participation. The next largest reductions come from repowering 1999-2002 model year trucks with 2003-2006 model year engines and retrofitting them with a DPF. This is targeted at 7.9% of the 1999-2002 model year fleet. The program would replace 3,559 trucks and repower 635 trucks with newer engines and DPFs. The program details are shown in Table 5-4.

The participation rate assumed for Program 3 is about 28% for the 1999-2002 model year fleet and 20% for the 1994-1998 model year fleet. This is an aggressive participation rate that might not be achievable with the assumed grant amounts without an extensive outreach effort. The program removes 7,993 tons of NOx, 322 tons of PM2.5, and 833 tons of ROG each year.

Table 5-4: Program 3 with $300 Million Funding in 2010

HHDT Strategy	Target Model Year	Potential Truck Population	Assumed Market Penetration	Emission Reduction Benefits (tons/year) NOx	PM2.5	ROG	Total Cost (million)
Replace with 2007+ truck	1994-1998	9,708	20.0%	4,186	172	445	$149.8
	1999-2002	8,089	20.0%	3,326	123	309	$124.8
Repower with 2003-2006 Engine with DPF	1999-2002	8,089	7.9%	481	27	79	$25.4
Total		17,797	23.6%	7,993	322	833	$300.0

5.3. Priorities for 2020

This section presents three hypothetical programs of strategies to reduce locomotive emissions in 2020. Table 5-5 shows a program of retrofits that would require approximately $30 million in funding. The funds would be used to retrofit 75 locomotives with DPFs (35 line haul and 40 switchers) and 75 more locomotives with SCR systems. This program would not be possible unless the current technological barriers to retrofits are resolved. As discussed in Section 3.3, the railroads would need to dedicate the affected line haul engines to the South Coast Air Basin, which may present some operational challenges. The program would eliminate 875 tons of NOx emissions, 13.3 tons of PM2.5 emissions, and 15.7 tons of ROG emissions per year in 2020.

Table 5-5: Program 1 with $30 Million Funding in 2020

Locomotive Strategy	Locomotive Type	Number of Locomotives	Emission Reduction Benefits (tons/year) NOx	PM2.5	ROG	Total Cost (million)
Retrofit with DPF	Line haul	35	0	11.8	13.5	$5.3
	Switcher	40	0	1.5	2.2	$3.0
Retrofit with SCR	Line haul	35	787	0	0	$14.0
	Switcher	40	88	0	0	$8.0
Total		150	875	13.3	15.7	$30.3

Table 5-6 shows a program with $100 million in funding. This program assumes that DPF and SCR retrofits do not prove feasible for locomotives, so replacement is the most effective and feasible approach. This program would replace 45 Tier 2 engines with Tier 4 engines, and would also replace 20 Tier 2 switchers with hybrid switchers (such as the Green Goat). Total annual emission reductions in 2020 would be 500 tons of NOx, 7.3 tons of PM2.5, and 8.8 tons of ROG.

Table 5-6: Program 2 with $100 Million Funding in 2020

Locomotive Strategy	Locomotive Type	Number of Locomotives	Emission Reduction Benefits (tons/year) NOx	PM2.5	ROG	Total Cost (million)
Replace with Hybrid Switcher	Line haul	N/A				
	Switcher	20	48	0.8	0.9	$15.0
Replace Rebuilt Tier 2 with Tier 4	Line haul	20	399	5.6	6.7	$48.0
	Switcher	25	53	0.8	1.2	$37.5
Total		65	500	7.3	8.8	$100.5

Program 3 assumes a significantly larger number of locomotive replacements, with a total funding requirement of $300 million. A total of 163 locomotives would be replaced – 127 with Tier 4 engines and 36 with hybrid switchers. The total emission reduction in 2020 would be 1,979 tons of NOx, 28.2 tons of PM2.5, and 33.8 tons of ROG, as shown in Table 5-7.

Table 5-7: Program 3 with $300 Million Funding in 2020

Locomotive Strategy	Locomotive Type	Number of Locomotives	Emission Reduction Benefits (tons/year) NOx	PM2.5	ROG	Total Cost (million)
Replace with Hybrid Switcher	Line haul	N/A				
	Switcher	36	86	1.5	1.6	$27.0
Replace Rebuilt Tier 2 with Tier 4	Line haul	91	1,818	25.4	30.5	$218.4
	Switcher	36	76	1.2	1.7	$54.0
Total		163	1,979	28.2	33.8	$299.4

5.4. Potential Contribution Toward AQMP Targets

For context, the emission reductions resulting from the programs presented above can be compared against the emission reductions needed to achieve attainment of the ambient PM2.5 and 8-hour ozone standards. The 2007 Air Quality Management Plan (AQMP) identifies the basin-wide emission reductions necessary achieve these standards. Table 5-8 compares programs 1 through 3 for each year to these emission reduction targets. The totals have been converted to tons per day for comparison to the AQMP targets. Programs 1 through 3 in 2010 are compared to the closest target year in the AQMP – the annual PM2.5 attainment date of 2014. Similarly, programs 1 through 3 in 2020 are compared to the closest target year in the AQMP – and the ozone attainment date of 2023.

Table 5-8: Program Emissions Benefits Compared to AQMP Targets for Attainment (tons per day)

Description and Date	NOx	PM2.5	ROG
Emissions Benefits, 2010			
2010 Program 1	1.1	0.2	0.4
2010 Program 2	6.2	0.2	0.4
2010 Program 3	21.9	0.9	2.3
Emission Reduction Targets for Attainment of the PM2.5 Standard, by 2014	192	14	59
Emissions Benefits, 2020			
2020 Program 1	2.4	0.04	0.04
2020 Program 2	1.4	0.02	0.02
2020 Program 3	5.4	0.1	0.1
Emission Reduction Targets for Attainment of the Ozone Standard, by 2023	383	N/A	116

Source for Targets: SCAQMD *Final 2007 Air Quality Management Plan*.

Table 5-8 shows that the potential programs of strategies would contribute a relatively small but not insignificant portion of the emission reductions required to achieve ambient air quality standards for PM2.5 in the South Coast Air Basin. The emission reductions from Program 3 in 2010 (21.9 tons per day of NOx and 0.9 tons per day of PM2.5) make up 11% of the total NOx reduction and 6% of the total PM reductions needed for PM2.5 attainment in 2014.

Contributions toward the targets for ozone attainment are more modest. The emission reductions from Program 3 in 2020 (5.4 tons per day of NOx) make up 1.4% of the NOx reductions needed for ozone attainment in 2023.

In summary, government-funded incentives for a goods movement emission reductions should focus on heavy-duty trucks in the short term (2010) and locomotives in the longer term (2020).[a] The most cost effective strategies in the short term involve replacing older trucks with model year 2007 or newer trucks, retrofitting older trucks with DPFs, and repowering older trucks with model year 2003-2006 engines. A 2010 incentive program of $300 million could achieve reductions of nearly 8,000 tons of NOx and 322 tons of PM2.5 per year. In the longer term, the most cost effective strategies will likely involve retrofitting locomotives with DPFs and/or SCR, replacing older locomotives with those meeting Tier 4 standards, and replacing older switcher locomotives with hybrid engines. The future commercial availability of locomotive retrofit devices is uncertain. A 2020 incentive program of $300 million could achieve reductions of nearly 2,000 tons of NOx and 28 tons of PM2.5 per year.

[a] Other major sources of goods movement emissions are ocean-going vessels, commercial harbor craft, and cargo handling equipment at ports and rail yards. As noted previously, this Action Plan does not include a program of recommended emission reduction strategies for these sources because the Ports and CARB are actively addressing these sources, and because SCAG does not (directly) plan for improvements to these elements of the region's goods movement system.

Endnotes

[1] American Association of Port Authorities, www.aapa-ports.org
[2] Southern California Association of Governments (2007), 2008 Regional Transportation Plan, Goods Movement Report, Draft, December.
[3] Southern California Association of Governments (2007).
[4] Leachman, R., Hicks, G., Fetty, G., Rieger, M. (2005): Inland Empire Railroad Mainline Study – Final Report.
[5] South Coast Air Quality Management District (2000). Multiple Air Toxics Exposure Study (MATES-II), Final Report, March.
[6] Port of Los Angeles and Port of Long Beach (2006): Final 2006 San Pedro Bay Ports Clean Air Action Plan, Technical Report, November 2006. Available at www.portoflosangeles.org/DOC/CAAP_Tech_Report_Final.pdf
[7] South Coast Air Quality Management District (2007): Proposed Modifications to the Draft 2007 AQMP Appendix III
[8] California Air Resources Board (2006): Proposed Emission Reduction Plan for Ports and Goods Movement in California, March 21.
[9] Tioga Group (2002). Empty Ocean Container Logistics Study, report prepared to Gateway Cities Council of Government, Port of Long Beach, and Southern California Association of Governments.
[10] The Carl Moyer Program considers the annualized capital cost in the numerator of the cost effectiveness ratio. The capital cost (CC) in this case is the amount of the grant given to the applicant for retrofitting existing equipment or purchasing new, lower-emission equipment. The annualized capital cost is calculated by the following formula:

ACC = CC x CRF, where CC is the capital cost and CRF is the capital recovery factor.

The CRF is defined as follows:

$CRF = [(1 + i)^n i] / [(1 + i)^n – 1]$, where n is the project life in years, and i is the interest rate (as a decimal fraction).

The annualized capital cost is, in essence, the amount of money that would have to be invested at the given interest rate and for the given number of years to earn a total equal to the capital cost. Another way of looking at capital recovery is that it is the number of dollars that would have to be set aside each year to repay the value lost due to depreciation, and to pay interest costs. Source: *The Carl Moyer Program Guidelines. Part IV. Appendix C. Cost Effectiveness Calculation Methodology*. California Air Resources Board, Sacramento, California, November 17, 2005. http://www.arb.ca.gov/msprog/moyer/guidelines/2005_Carl_Moyer_Guidelines_Part4.pdf
[11] See http://www.epa.gov/oms/locomotv.htm#2008final
[12] Port of Long Beach (2007): Port of Long Beach Air Emissions Inventory, 2005. Prepared by Starcrest Consulting Group, LLC. September. Available at http://www.polb.com/civica/filebank/blobdload.asp?BlobID=4412
[13] Port of Los Angeles (2007): Port of Los Angeles Inventory of Air Emissions, 2005. Technical Report. Prepared by Starcrest Consulting Group, LLC. September. Available at http://www.portoflosangeles.org/DOC/2005_Air_Emissions_Inventory_Full_Doc.pdf
[14] See http://www.epa.gov/oms/locomotv.htm#2008final
[15] Port of Long Beach (2007).
[16] Port of Los Angeles (2007).
[17] Port of Long Beach (2007).
[18] Port of Los Angeles (2007).
[19] Entec UK Ltd. (2005): Service Contract on Ship Emissions: Assignment, Abatement and Market-based Instruments, Task 2b-NOx Abatement, Final Report, August.
[20] Port of Long Beach (2007).
[21] Port of Los Angeles (2007).
[22] Port of Long Beach (2007).
[23] Port of Los Angeles (2007).